ELEMENTARY ENTOMOLOGY

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PREFACE

During recent years there has been increasing demand for short courses in elementary entomology. For several years past the authors have been endeavoring to present such courses to their students, but have encountered the difficulty that no textbook was available which met their needs. This book is, therefore, the authors' effort to furnish such a text for beginners, and if it is found useful to them and to the increasing number of teachers who are endeavoring to instruct them in the subject, the authors will feel well repaid. The work is confessedly very largely a compilation from the works of others (as, indeed, any such work must be), and it is obvious that many errors and defects may have been overlooked, although the authors have spared no pains to eliminate them. To those who observe such shortcomings, or who may be able to offer suggestions for the improvement of the book when revised, the authors will be under great obligation.

It was originally intended to include several chapters treating of the various insect pests affecting crops and domestic animals, but it was found that such a work would be too cumbersome; indeed, it is usually not possible to cover both elementary and economic entomology in a single course. The economic side of the subject has, however, been made the dominant note in the following pages, and the forms discussed are mostly those of economic importance. There is a popular belief, often held by young agricultural students, that the chief subject matter of a course in entomology should be a discussion of the common injurious insects. Experience has shown that such an idea is fallacious, and that, from the standpoint of practical utility as well as from that of general culture, a knowledge of the structure, habits, and classes of insects in general is much the more important phase of entomology for academic study. Economic entomology is important and should

not be neglected, but general entomology is the foundation upon which it must be erected, and without a knowledge of the elements of entomology a course in economic entomology will have but little meaning to the average student, whereas if the more general knowledge of the subject has been mastered, the study of the various insect pests may be profitably pursued by the individual, even if he has not been able to take a systematic course in that phase of the subject.

Students should be encouraged to make free use of the standard textbooks for reference and to aid in the identification of specimens. Much interest may be added to the course by securing the available entomological publications of the state agricultural experiment stations (a list of which stations may be found in the Appendix) and those of the Bureau of Entomology, United States Department of Agriculture, Washington, D.C., many of which may be had free of charge.

The work outlined in the study of life histories, in collecting, and in the identification of insects is necessarily largely suggestive. The amount and nature of such work must depend upon the time available, the equipment, the time of year, and the local surroundings of the school, and must be determined by every teacher to suit his own conditions. It should be emphasized, however, that a maximum of laboratory and field work and a minimum of book work will probably give the average student a better knowledge of insect life than the opposite arrangement, as the subject is one in which the student must secure his knowledge directly from the material, if it is to have much real meaning to him.

The senior author is entirely responsible for the preparation of Parts I and II, and the junior author for Part III, although they have consulted together on all parts of the work.

Many of the half-tone illustrations are from photographs by the senior author or from those of Dr. C. M. Weed, his predecessor at the New Hampshire Agricultural Experiment Station, while several new line drawings have been prepared for the work by Alma Drayer Jackson and Iris L. Wood, for whose generous aid the authors are greatly indebted. The remaining illustrations

have been drawn from various sources, as indicated in the titles, but the authors are under particular obligations to the following persons for the loan of cuts for electrotyping: Dr. L. O. Howard, Chief of the Bureau of Entomology, United States Department of Agriculture; Professor F. L. Washburn, State Entomologist of Minnesota; Dr. J. B. Smith, State Entomologist of New Jersey; Dr. V. L. Kellogg, of Leland Stanford Junior University; Dr. W. E. Britton, State Entomologist of Connecticut; Dr. E. P. Felt, State Entomologist of New York; Professor G. W. Herrick, of Cornell University; Professor C. P. Gillette, Director of the Colorado Agricultural Experiment Station; P. Blakiston's Son & Co., and D. Appleton and Company.

The authors are also greatly indebted to the following entomologists for reading portions of the manuscript and criticizing the keys for the identification of insects, which criticisms have added greatly to the accuracy and reliability of the work: Professor Herbert Osborn, Dr. C. T. Brues, Mr. C. W. Johnson, Mr. Nathan Banks, Dr. J. B. Smith, Dr. Harrison G. Dyar, and Dr. A. D. MacGillivray.

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ELEMENTARY ENTOMOLOGY

CHAPTER I

INTRODUCTION

A professor of entomology in one of the leading universities has recently been quoted as saying that this is "the age of insects." Doubtless most of us have been accustomed to consider it "the age of man," but although man's sway is dominant in all parts of the earth, there is considerable evidence that, from a purely biological standpoint, insects are the most characteristic form of life of the present age, and the statement quoted challenges our attention for more than a passing consideration.

That such a statement should be made by a well-known entomologist, and should be widely quoted, is significant of the present attitude of the public toward insect life, which has changed radically during the last generation. Not many years ago the entomologist, or "bug collector," was looked upon as a harmless individual who amused himself with his hobby; and as he was met with his butterfly net, the passer-by might lift his eyebrows as if questioning whether a grown man who would devote himself to such insignificant creatures was really quite normal.

To-day the public has come to appreciate that insect life plays a most important part in the economy of our civilization. Some of the problems which require the work of the trained entomologist are worthy of the highest scientific training and best executive ability.

Insects and disease. The modern methods of sanitation for the control of malarial fever and yellow fever involve the control of mosquitoes, which transmit these diseases. More and more the sanitary measures which are making the tropics habitable for the more northern races of man are being made possible by a knowledge of the relation of insect life to the transmission of disease. Even the common house-fly, formerly considered a mere nuisance,

is now known to carry typhoid fever and probably various intestinal disorders, to which a large part of our infant mortality is due; and it has been well said that, during the Cuban War, probably more American soldiers were killed through the agency of flies carrying typhoid germs than by Spanish bullets.

Injury to crops. In their economic relations the insects affecting crops are by all odds of the most importance, many of them causing a loss of several million dollars a year to the farmers of the United States. The boll weevil destroys over $25,000,000 worth of cotton in Texas and Louisiana alone, and 10 per cent of the wheat crop of the entire country, valued at $60,000,000, is usually destroyed by insect pests. It has been estimated by competent authorities that 10 per cent of the total value of the farm products of the United States is annually lost by the ravages of insect pests, amounting to nearly $800,000,000 per annum.

Injury to domestic animals. Domestic animals are affected by various insects, such as the warble, or ox-bot, and the screw worm, — which affect cattle, — the sheep maggot, and many others, including the ticks, which carry Texas fever and other diseases; so that the annual loss to live stock through insects is estimated at $175,000,000 per year.

Injury to household and stored goods. Housekeepers, manufacturers, and wholesale dealers must take into consideration the insect life which affects all sorts of vegetable and animal products, and the aggregate loss due to the insect pests of household and stored goods must in the aggregate be a considerable item in domestic economy and mercantile business.

Productive insects. A few insects contribute directly to the wealth of the world: the silkworm produces over $200,000,000 worth of silk annually, and the product of the busy honey-bee amounts to over $20,000,000 per year in the United States alone.

Beneficial insects. The direct relations of insects to mankind are by no means the most important phases of their ecology. The rôle of insects in the pollenization of fruits and flowers is fundamental to the successful fruiting and perpetuation of a large proportion of common plants. Again, a large number of insects prey upon or live within the bodies of other insects, and constitute the most important factor in the natural control of injurious species. Were it not

for these beneficial forms, which prevent the normal increase, many of our common injurious insects would become so numerous as to practically prohibit the growth of crops affected.

Value of study of insects. The strictly economic aspect of insect life is not, however, the only phase worthy of our attention and study. The apathy with which the study of entomology was formerly treated was unquestionably due to the general lack of interest in biology until recent years. During the last generation it has been more and more appreciated that man is but a child of nature, and that he can learn much in the proper conduct of his affairs by a study of the laws of life in general, whether of the uncivilized races of mankind, of insects, or of microscopic bacteria or protozoa. Our grandfathers hardly knew that bacteria existed; to-day most of the science of pathology, and much of the practice of medicine, is based on an understanding of their life. It would seem, therefore, that insect life should furnish a large field for the student of general biology, and more and more biological problems of fundamental importance are being worked out through studies of insects.

That this should be the case is extremely obvious when we remember that there are over 300,000 known species of insects, including over four fifths of the described species of animals, and that at the rate at which they are being described, it has been estimated that over a million species exist. The immense number of insects, both of species and of individuals, is undoubtedly due to their varied structure, which enables them to live under all possible conditions. Thus the larvæ of many different species are adapted so that they live entirely in water, others bore in trees and plants, some are subterranean, while still others inhabit the tissues of domestic animals or of other insects. By the aid of their wings the adults spread rapidly and are thus able to migrate when necessity arises. Thus the insects possess such diversity of structure and habit that they are able to live under all external conditions, and on account of their immense numbers they have been able to adapt themselves to a changing environment which would have entirely obliterated classes or species few in number.

Not only are insects the most abundant form of animal life, but they exhibit the highest degree of intelligence of any of the lower or invertebrate animals. The wisdom of the ant and the industry

and domestic economy of the honey-bee are proverbial, and new observations are constantly showing the wonderful intelligence, if it may be so called, evinced by many insects hitherto but little known. No class of animals is more fascinating or better rewards the study of the nature lover, as may be slightly appreciated from the perusal of the habits described in succeeding pages.

It may now be evident, in view of the immense preponderance of species and individuals of insects in the animal kingdom, and their important rôle in the economy of nature, that there is some ground for describing the present as "the age of insects," though the term is of course used from a purely biological standpoint.

PART I. THE STRUCTURE AND GROWTH OF INSECTS

CHAPTER II

INSECTS AND THEIR NEAR RELATIVES

If we are to study insects, it is necessary that we should have a clear conception of just what an insect is and how insects may be distinguished from other animals. Most of us recognize bees, flies, beetles, and butterflies as insects, but other forms of insect life we

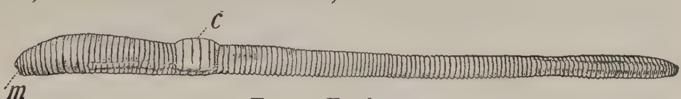

FIG. 1. Earthworm

m, mouth; *c*, girdle, or clitellum. (After Jordan and Heath)

should probably call "worms," and various insectlike animals are commonly termed "insects."

The animal kingdom is divided into two large groups of animals, — those having a backbone, the Vertebrates, and those without a backbone, the Invertebrates. In the former are included all the

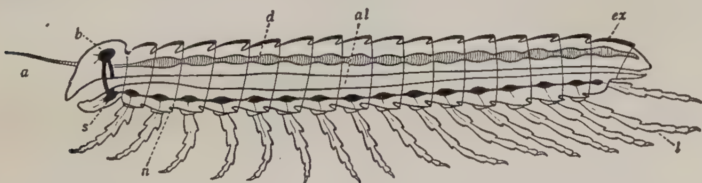

FIG. 2. Diagram to express the fundamental structure of an arthropod

a, antenna; *al*, alimentary canal; *b*, brain; *d*, dorsal vessel; *ex*, exoskeleton; *l*, limb; *n*, nerve chain; *s*, subesophageal ganglion. (After Schmeil, from Folsom)

higher animals, such as the fishes, reptiles, birds, and mammals; while in the latter are included all the lower forms of life, which are usually smaller in size and soft-bodied, as the molluscs, echinoderms, worms, insects, and their relatives.

The Invertebrata are divided into several branches, or phyla (singular, phylum), which divisions are based on fundamental differences in the body structure of the animals in these groups. Of these phyla there are two which have the body made up of a series of segments and were at one time classed together as the *Articulata.*

FIG. 3. A lobster; a typical crustacean

The first of these two phyla, the *Vermes*, or worms, has no jointed appendages, while the second, the *Arthropoda*, is characterized by having jointed appendages on either several or all segments of the body, from which the term "Arthropoda," from *arthron* (joint) and *pous* (foot), is derived. The Arthropoda include the insects, spiders, myriapods, and crustaceans, all of which are related by the possession of these jointed appendages. The distinctions between

these four classes are based largely upon the manner in which the different segments are grouped together to form compact and distinct parts of the body, and by the number and position of the appendages.

The Crustacea include the lobsters, crabs, crayfish, shrimps, barnacles, sow-bugs, etc., and are primarily distinguished from all other arthropods by the fact that they breathe by means of gills and live either in the water or in damp places. The body is divided into two main regions, the anterior segments being usually covered by a single large shell forming the head-thorax, or cephalothorax, while the remaining segments form the abdomen. Each segment usually bears a pair of appendages. On the head are found two pairs of antennæ, and on the thorax and abdomen are numerous appendages fitted for walking or swimming.

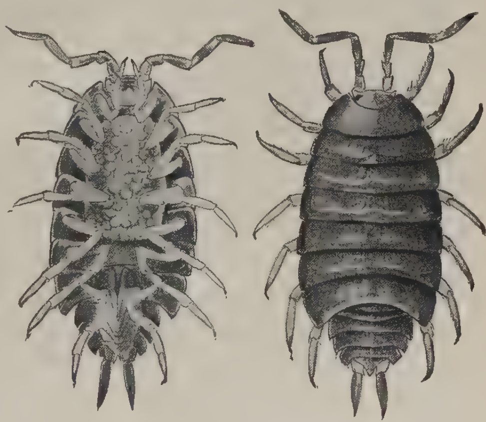

FIG. 4. Sow-bug, or pill-bug (*Porcellio laevis*) Enlarged. (After Jordan and Heath)

The only crustacean commonly mistaken for an insect is the little sow-bug, or pill-bug, found in greenhouses, under boards, or in damp places (Fig. 4). These rarely do any damage and may be readily distinguished from insects by the two pairs of antennæ and the numerous appendages. The gills are to be found under plates on the lower side of the abdomen.

The Arachnida include the spiders, scorpions, ticks, and mites, and are almost entirely terrestrial. The body is divided into the cephalothorax and abdomen, as in the Crustacea, but there are no antennæ and but four pairs of legs. Although ticks and mites are not insects, yet they are so nearly related, and their injuries to plants and animals are so similar to insect depredations, that they are commonly included in economic entomology. Spiders are, if anything,

beneficial, though they feed on beneficial as well as on injurious insects, while scorpions are found only in tropical countries and are chiefly a nuisance on account of their poisonous sting.

FIG. 5. A spider; a typical arachnid

The Myriapoda include the myriapods and centipedes, commonly called thousand-legs. Their body consists of a distinct head and a long abdomen, all of the segments of which are similar, and each bears one or two pairs of legs, so that they are readily distinguished from all other arthropods. In many ways the myriapods are more closely related to the insects than either of the other classes mentioned above. A few species sometimes injure vegetables or fruits lying on or in the ground, and these are considered as within the sphere of economic entomology; but for the most part myriapods are harmless, although the house centipede is a nuisance and is abhorred by the housekeeper. Some of the tropical myriapods reach relatively enormous size, being several inches long, and bear poison fangs in connection with the mouth-parts.

FIG. 6. A myriapod

The Insecta, or Hexapoda, include the true insects, which form the largest group of animals as far as both the number of different species and the number of individuals are concerned. About 300,000 different species have already been described, while there is probably a total of 1,000,000 species in existence. The known species form over four fifths of the total number of

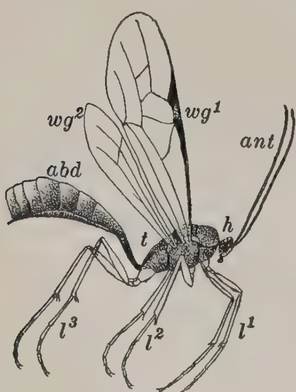

FIG. 7. A parasitic fly, showing parts of a typical insect

ant, antennæ; *h*, head; *t*, thorax; *abd*, abdomen; *wg*, wings; *l*, legs

animals now described. The adult insects are readily recognized from the other classes of arthropods, but many of the immature forms, such as maggots, lack the typical characteristics of the group. The segments of the body of an insect are grouped into three distinct regions, — the head, the thorax, and the abdomen. The head bears a single pair of feelers, or antennæ, the mouth-parts, and the compound eyes. The thorax bears three pairs of jointed legs and in the adult stage usually two pairs of wings, though in the flies there is but a single pair and in a few orders wings are lacking. The abdomen is usually without appendages in the adult state, although on caterpillars and other immature stages prolegs, or false legs, which are not segmented, are often found.

Comparative Structure of the Classes of Arthropoda

Class	Parts of Body			Antennæ	Eyes	Legs
Winged Insecta	1 Head,	2 thorax,	3 abdomen	One pair	Compound	Six
Wingless Myriapoda	1 Head,		2 abdomen	One pair	Compound	One or two pairs per segment
Arachnida	1 Head-thorax,		2 abdomen	None	Simple	Eight
Aquatic Crustacea	1 Head-thorax,		2 abdomen	Two pairs	Compound	Many

CHAPTER III

ANATOMY OF INSECTS — EXTERNAL

Body structure. The extinct ancestors of the insects were doubtless elongate, wormlike animals composed of a series of cylindrical segments very similar in structure and with a pair of jointed appendages attached to each segment. The mouth being

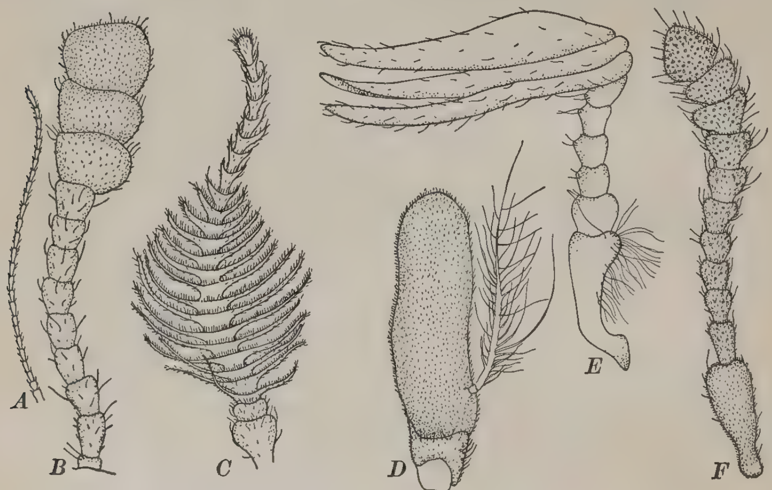

FIG. 8. Types of insect antennæ

A, filiform, from grasshopper (*Schistocerca americana*); *B*, clubbed, or clavate, from tenebrionid beetle (*Nyctobates pennsylvanicus*); *C*, pectinate, or feathered, from a moth; *D*, aristate, with dorsal plumose arista, from a fly; *E*, lamellate, from a May-beetle (*Lachnosterna fusca*); *F*, moniliform, from a beetle

at the anterior end, the appendages near it were developed to secure and tear up the food. Thus the mouth-parts were gradually evolved, and the segments bearing them grew closer together until they coalesced and formed a single well-defined region, the *head*. With the development of wings the appendages of the posterior segments were useless and soon disappeared, and the legs on the three segments immediately back of the head became

further specialized as organs of locomotion. With the development of the large muscles necessary for the propulsion of the wings and legs, these three segments back of the head became sharply differentiated from the rest, so that they now form a quite distinct region, the *thorax*. The remaining posterior segments, called the *abdomen*, having lost most of their appendages, are quite similar in form, with the exception of those at the extreme posterior end, where the shape of the segments and of their appendages has been modified in connection with the external sexual organs. The insect is therefore divided into three well-defined parts, — the head, the thorax, and the abdomen, — which are composed of more or less visible segments.

The head. The embryology and nervous system of the head show that it was originally composed of six segments, almost no traces of which are now discernible except their appendages, of which four pairs are recognizable as homologous with the thoracic legs and the abdominal appendages of lower forms. These appendages consist of the feelers, or antennæ, and three pairs of mouth-parts. The head also bears a pair of compound eyes and often a variable number of simple eyes, or ocelli.

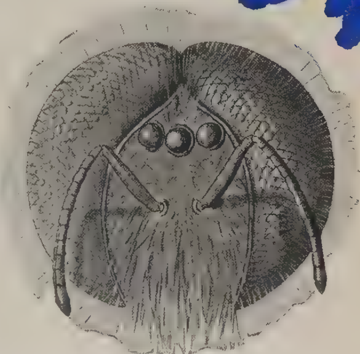

FIG. 9. Head of drone bee; showing compound and simple eyes

(After A. B. Comstock)

Antennæ. The antennæ are often called feelers, indicating their principal function as sense organs, which will be discussed in considering the senses. The shape of the antennæ is very different in different groups of insects, as is also the number of segments, both of which characters are of the greatest importance in distinguishing the various groups. In the case of the katydid the threadlike antennæ are much longer than the body, while in some flies they are reduced to mere knobs with a single strong bristle. The different shapes of the segments give rise to many different characteristic types of antennæ, some of the more important of which are shown in Fig. 8. In many cases, notably in the moths

and mosquitoes, the antennæ of the sexes are quite different, so that the sexes are readily distinguishable.

Eyes. On each side of the head are found the large compound eyes, often forming the larger part of the side of the head, and sometimes, as in the dragon-fly and horse-fly, forming the major portion of the head. The compound eyes are usually oval or circular in outline, and are called compound because, when examined under a lens, they are seen to be composed of large numbers of hexagonal areas, called *facets*. The number of these facets varies from 50 in certain ants to 4000 in the house-fly and

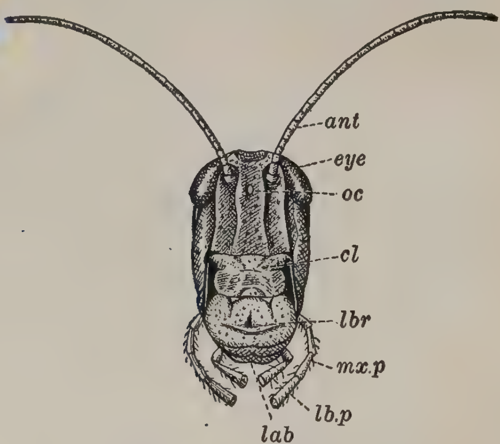

Fig. 10. Face of grasshopper

ant, antenna; *cl*, clypeus; *eye*, compound eye; *lab*, labium; *lbr*, labrum; *lb.p*, labial palpi; *mx.p*, maxillary palpi; *oc*, ocellus

27,000 in certain sphinx moths. Between the compound eyes, on the front, or vertex, of the head, are two or three small oval or circular simple eyes, called *ocelli*. Caterpillars and other larvæ have no compound eyes, but on either side of the head have a group of from four to six ocelli. In many flies and bees the compound eyes of the male are larger and closer together than those of the female, this being due, possibly, to the male's leading a more active life.

Mouth-parts. The mouth-parts are of prime importance, both from an economic and from a systematic standpoint. Upon their structure depends the kind of insecticide which may be effectively

used, and their structure is so constant and characteristic in different groups as to furnish one of the best means of classification. Most of the orders possess one of the two main types of mouth-parts, — those formed for *biting* (mandibulate), and those formed for *sucking* (suctorial, or haustellate). The biting type, as found in the grasshopper, is the more typical, and will therefore be discussed first.

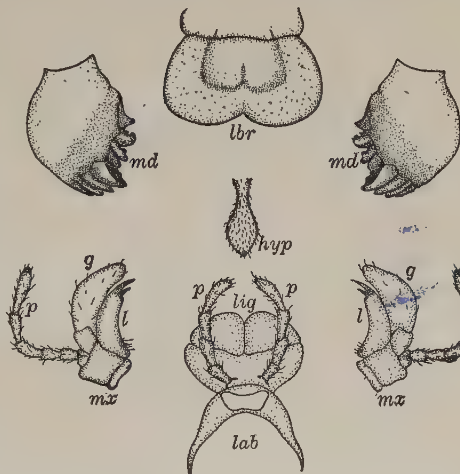

FIG. 11. Mouth-parts of grasshopper, typical biting or mandibulate mouth-parts

lbr, labrum, or upper lip; *md*, mandible; *mx*, maxilla; *lab*, labium, or lower lip; *p*, palpus; *g*, galea; *l*, lacinia; *lig*, ligula; *hyp*, hypopharynx

The *labrum*, or upper lip, is a simple flap projecting over the upper part of the opening of the mouth and covering the mandibles. It is hinged on the posterior margin, but otherwise is free and may be slightly protruded or retracted, to aid in bringing food to the mandibles.

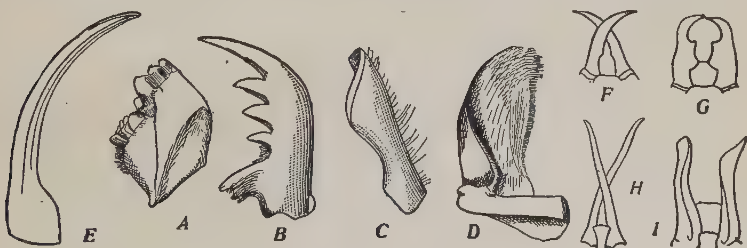

FIG. 12. Various forms of mandibles

A, grasshopper (*Melanoplus*); *B*, tiger beetle (*Cicindelidae*); *C*, bee (*Apis*); *D*, Onthophagus; *E*, lace-winged fly (*Chrysopa*); *F–I*, soldier termites. (After Hagen, from Folsom)

The *mandibles*, or jaws, are composed of a single toothlike piece and move in a transverse plane. The form of the mandibles

is modified according to the food of the insect. Thus, in the grasshopper and similar insects feeding upon vegetation the mandibles are short, with strong teeth at the tip and behind them a crushing or grinding surface. In carnivorous and predacious insects the mandibles are usually long, slender, and sharply toothed, adapted for grasping the prey or tearing flesh. In certain of the Neuroptera, as in the aphis-lion (see page 92), the mandible has a deep groove on the inner surface, through which the juices of the plant-lice are sucked. In soldier ants the mandibles are developed as effective weapons, while in other forms they are otherwise specialized according to the food habits of the insect; but they are always essentially biting organs.

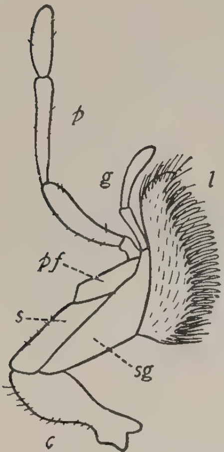

FIG. 13. Maxilla of a ground beetle (*Harpalus caliginosus*), ventral aspect

c, cardo; *g*, galea; *l*, lacinia; *p*, palpus; *pf*, palpifer; *s*, stipes; *sg*, subgalea (After Folsom)

Beneath the mandibles are the *maxillæ*, or under jaws. The maxillæ are much more complex, consisting of a basal portion (stipes) which is hinged to the head (by the cardo) and which bears three lobes, — the palpus, galea, and lacinia. The palpus is composed of four or five segments, resembles a miniature antenna, and, like it, is a sensory organ. The inner lobes, the lacinia, are usually provided with teeth or spines and aid the mandibles in holding and masticating the food.

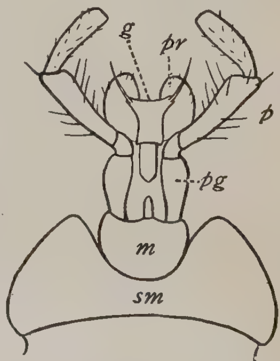

FIG. 14. Labium of a ground beetle (*Harpalus caliginosus*), ventral aspect

g, united glossæ, termed the glossa; *m*, mentum; *p*, palpus; *pg*, palpiger; *pr*, paraglossa; *sm*, submentum. The median portion of the labium beyond the mentum is termed the ligula. (After Folsom)

The third pair of mouth-parts have grown together on the median line so as to form a single piece, known as the *labium*, or underlip. In the embryo this is composed of a pair of appendages similar to the maxillæ, and for this reason is sometimes

termed the *second maxillæ.* The labium forms the floor of the mouth and assists the mandibles and maxillæ with the food. It is hinged to the head at its base (by the *mentum*), and projecting from either side is a *palpus*, similar in form and function to the maxillary palpi. Between the palpi are one or two pairs of lobes, the *ligula*.

Projecting into the cavity of the mouth from the inner surface of the labium is the *hypopharynx*, or tongue. This in the

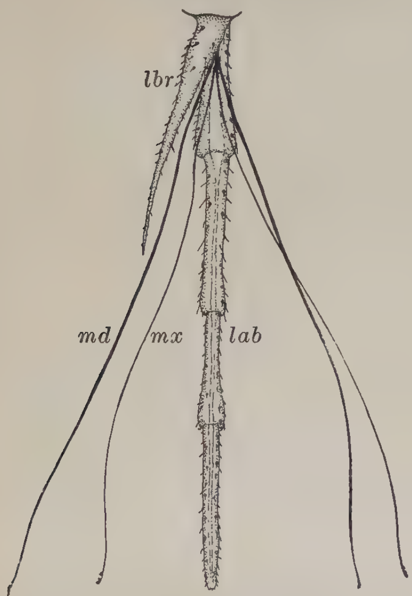

FIG. 15. Mouth-parts of the squash-bug

lab, labium, forming a sheath for the other parts; *lbr*, labrum, fitting into the lower part of the suture of the labium; *md*, mandible; *mx*, maxilla. Mandibles and maxillæ pulled out of labium

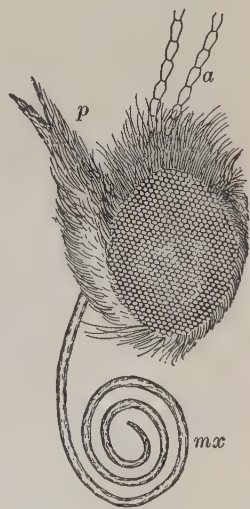

FIG. 16. Side view of head of butterfly, with part of antennæ (*a*) removed, showing mouth-parts

mx, maxillæ; *p*, labial palpus

grasshopper is a fleshy, tonguelike organ, but in some orders it is quite differently developed. The salivary glands open near its attachment.

Suctorial type of mouth-parts. The mandibulate mouth-parts of the different orders are all of so similar a type as to be apparently homologous. The suctorial mouth-parts consist of several

very distinct types, entirely dissimilar in structure and origin, resembling each other only in that they enable the insect to suck or lap its food rather than to bite it.

FIG. 17. Cross section of proboscis of cotton-worm moth, showing concave inner faces of maxillæ locked together to form the sucking tube

(After Comstock)

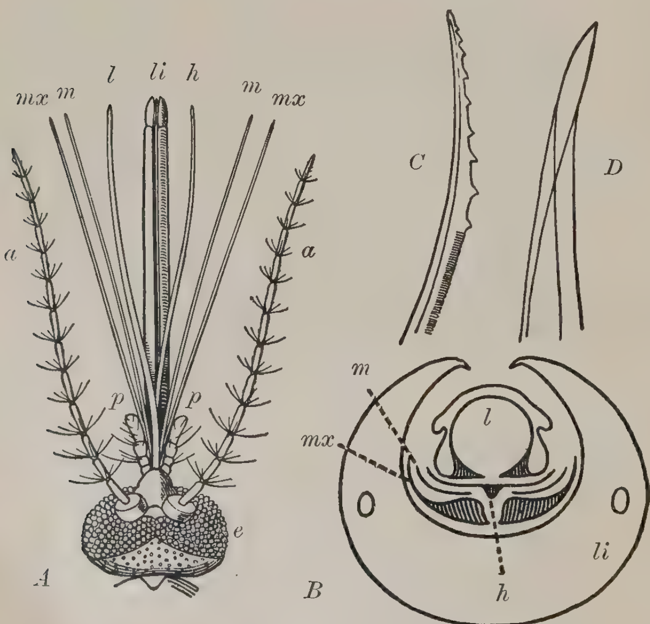

FIG. 18. Mouth-parts of female mosquito (*Culex pipiens*)

A, dorsal aspect; *B*, transverse section; *C*, tip of maxilla; *D*, tip of labrum-epipharynx; *a*, antenna; *e*, compound eye; *h*, hypopharynx; *l*, labrum-epipharynx; *li*, labium; *mx*, maxilla; *m*, mandible; *p*, maxillary palpus. (After Folsom and Dimock)

Hemiptera. In the Hemiptera, or bugs, the labium forms a long, jointed beak, or rostrum (Fig. 15). This rostrum is cylindrical in section, and its evolution from the type of labium found in the grasshopper may be understood by conceiving the labium of the latter to be greatly elongated and then curled up on either side until the lateral margins meet on the median line above, forming a suture, as seen in the hemipterous beak. At the base of this suture is found a triangular labrum closing the base of the tube. The mandibles and maxillæ are long, bristlelike or needlelike structures, sharply pointed and often bearing barbs at the tip, and the maxillæ are locked together so as to form a tube through which the juices are sucked.

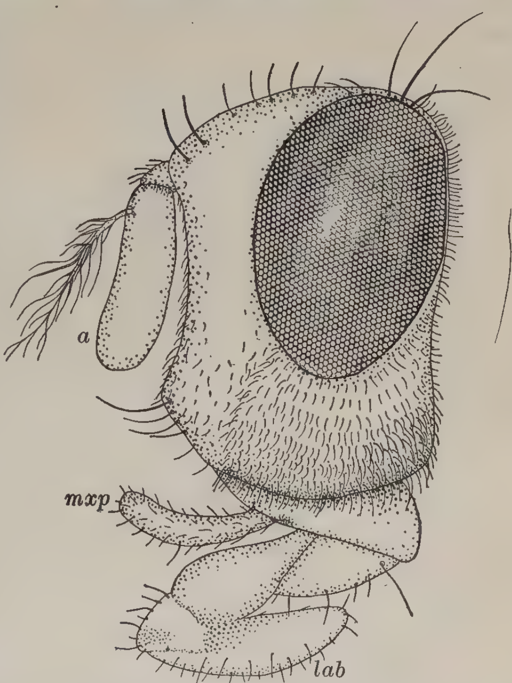

FIG. 19. Side view of head of a fly
a, antenna; *mxp*, maxillary palpus; *lab*, labellum

Lepidoptera. The moths and butterflies possess a very different style of sucking tube, or proboscis, which is curled up under the head like a watch spring. This is composed of the two maxillæ, whose inner faces are concave and which lock together so as to form a tube which opens into the mouth. All the other mouth-parts are almost entirely absent in most forms, except the labial palpi. It is evident that this type of mouth-part is only adapted to sucking nectar from flowers and is never injurious to vegetation, while often adapted for pollenizing flowers which the moths frequent. The caterpillars of moths and butterflies have biting mouth-parts similar to those of the grasshopper.

Diptera. The flies have several types of mouth-parts, all essentially suctorial. Those of the horse-fly and mosquito are good examples of the piercing type (Figs. 18, 20). Superficially they resemble those of the Hemiptera, but the sheath of the beak is not so strong and is quite open above, and there are six lancetlike organs which in the horse-fly are quite strongly developed. The esophagus is controlled by sets of muscles which make it an effective bulb for pumping up the food. The common house-flies and blow-flies have mouth-parts (Fig. 19) adapted for rasping or lapping rather than for piercing, though the liquid food is sucked up in much the same way. The proboscis consists principally of the very complex labium, or lower lip, which is very much expanded at the tip to form a pair of fleshy lobes. When looked at under the microscope, the tip of the proboscis is seen to contain a series of grooves and transverse horny ridges with sharp, projecting edges. With these rasplike projections the fly is enabled to scrape the surface of the food and gradually loosen small particles, which are dissolved or carried in the saliva to the mouth.

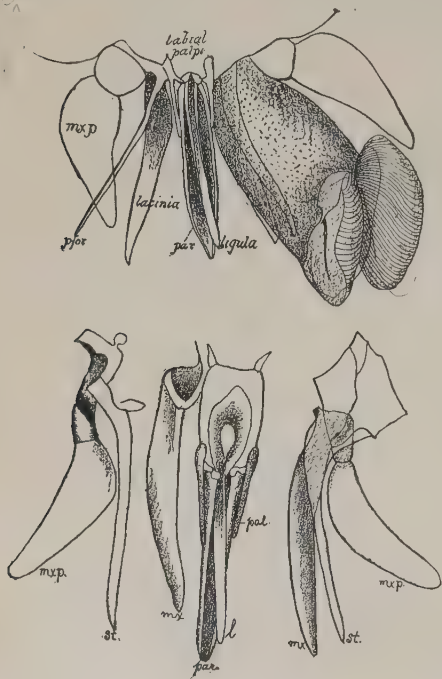

FIG. 20. Mouth-parts of horse-fly (*Tabanus*)

Upper figure showing mouth-parts separated, and lower figure showing lancets dissected out. (After J. B. Smith)

Hymenoptera. The mouth-parts of the Hymenoptera include both biting and sucking types. The saw-flies and ants (Fig. 22) have well-developed biting mouth-parts, which are used as such, while in the wasps and bees the maxillæ and labium form a tube

around the greatly elongated tongue (hypopharynx) which is used for lapping and sucking, though the mandibles are still functional and are used in shaping wax and pollen.

It should be noted that in several of these orders having suctorial mouth-parts in the adult stage the larvæ have true biting mouth-parts. Caterpillars of all the Lepidoptera and the larvæ of many

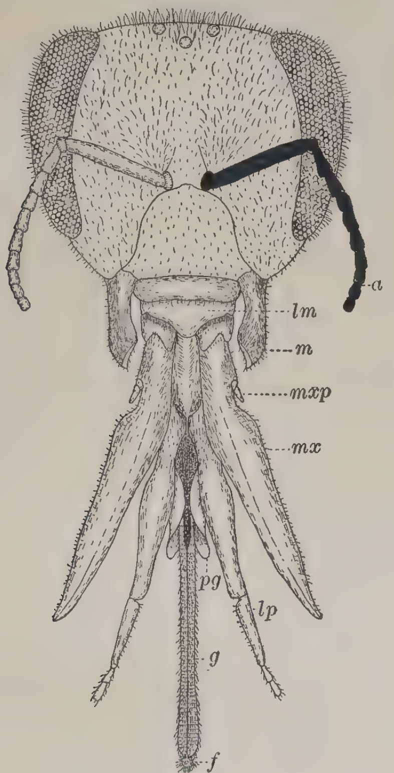

FIG. 21. Mouth-parts of the honey-bee

a, antenna; *f*, labellum; *g*, glossa, or tongue; *lm*, labrum; *lp*, labial palpi; *m*, mandible; *mx*, maxilla; *mxp*, maxillary palpus; *pg*, paraglossa

families of flies and Hymenoptera have biting mouth-parts and are injurious to vegetation, while the adults may be entirely harmless. This difference in the mouth-parts of the same insect in different stages must be borne in mind in considering insecticides for them.

We have stated that the structure of insects often determines the method of treating them. This may now be understood, for it is evident that a poison such as Paris green, applied to the food of a sucking insect, such as a plant-louse, would not be taken into the mouth through the sucking mouth-parts, which extract only the juices beneath the surface, while it might be entirely effective against an insect with biting mouth-parts, which consumed the surface covered by the poison. A better understanding of these simple facts of insect anatomy would save American farmers thousands of dollars every year, now lost through ignorance.

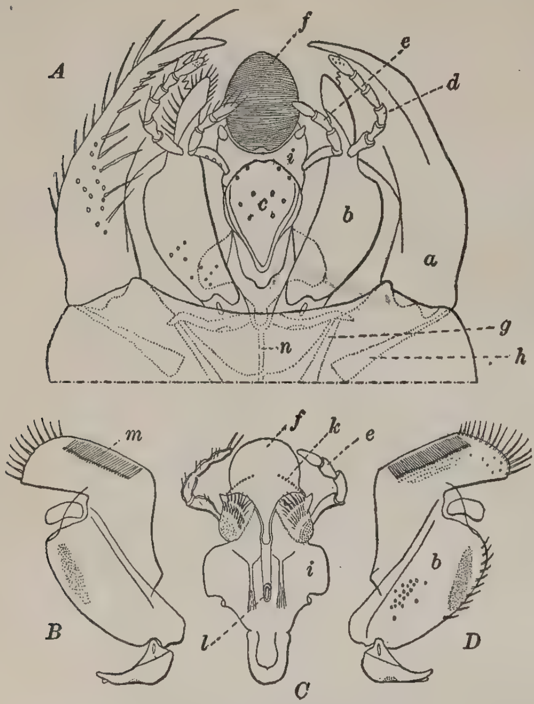

FIG. 22. Mouth-parts of an ant (*Myrmica rubra*)

A, seen from the lower side *in situ; B* and *D*, maxillæ; *C*, labium seen from the upper side, detached; *a*, mandible; *b*, maxilla; *c*, mentum; *d*, maxillary palp; *e*, labial palp; *f*, glossa or tongue; *g*, adductor muscle of mandible; *h*, abductor muscle of mandible; *i*, labium; *k*, gustatory organs; *l*, duct of salivary glands; *m*, maxillary comb; *n*, gular apodeme. (After Janet, from Wheeler)

Thorax. The thorax is the middle region of the body, composed of the three segments back of the head, which are called the *prothorax*, *mesothorax*, and *metathorax* respectively. As previously indicated, the differentiation of the thorax has been incidental to the development of the wings, and the structure of the thorax is determined by the development and use of the organs of locomotion. A pair of jointed legs is attached to each segment and

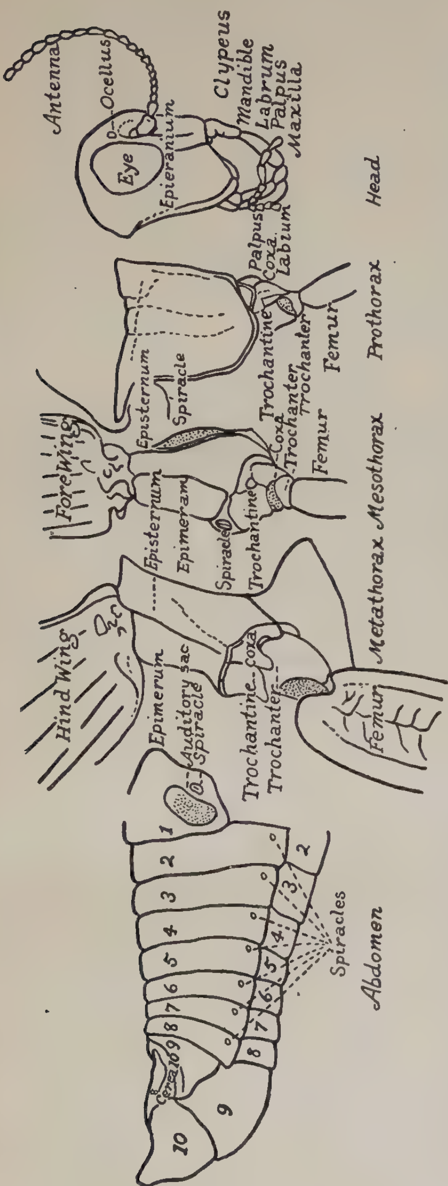

FIG. 23. Side view of a locust with the thorax separate from the head and abdomen and divided into its three segments

(After Packard)

the mesothorax and metathorax of most adult insects bear a pair of wings. The prothorax is usually smaller than the two posterior segments, the relative size of which depends upon which pair of wings is the better developed. The dorsal surface, or back, of a thoracic segment is called the *tergum*, or *notum*, the ventral or under surface is the *sternum*, and each side is a *pleurum*. These parts are further divided by sutures into distinct plates, or *sclerites*, to which the appendages are articulated. The development, shape, size, and position of these sclerites are characters of such uniformity that the sclerites are used in classifying insects, in much the same way as are the bones of the vertebrate animals.

Legs. The legs articulate with the sternum and pleurum and consist of five parts, — the *coxa*, *trochanter*, *femur*, *tibia*, and *tarsus*. The base of the coxa forms the joint of the leg to the body, which is either of the ball-and-socket or of the hinge type. The trochanter is a small, intermediate segment, which in parasitic Hymenoptera is double. The femur is the largest segment in the leg, and in grasshoppers and other jumping insects is strongly developed by the muscles within. The tibia is usually long and slender. The tarsus is usually composed of several similar segments, five being the typical number. The last segment usually bears a pair of sharp claws in adult insects and a single claw in larvæ. Between the claws of most adult insects is a little pad, called a *pulvillus*, or *empodium*, a suckerlike organ which enables them to walk upon smooth surfaces and to cling to objects when upside down.

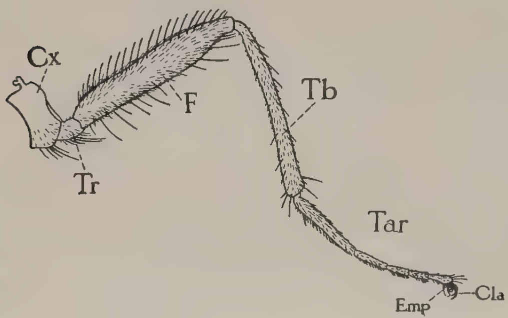

FIG. 24. Typical insect leg

Cx, coxa; *Cla*, claws; *Emp*, empodia; *F*, femur; *Tar*, tarsal segments; *Tb*, tibia; *Tr*, trochanter. (After Snodgrass, United States Department of Agriculture)

Nearly all adult and most larval insects have three pairs of thoracic legs, but many boring and parasitic larvæ have lost them entirely. The legs are often greatly modified according to the habits of the insect, not only for locomotion, but for grasping, digging, and other purposes. The legs of most beetles are typical of walking insects. In jumping insects, like the grasshopper and flea beetles, the hind femora are greatly developed. In digging insects, such as the mole cricket and cicada nymphs, the tibia and tarsus of the forelegs are developed as shovels. The forelegs of many predacious insects, such as the mantis, assassin bugs, and others, bear teeth upon the opposing surfaces of the tibia and femur, which make them efficient grasping organs. The legs of the bees are highly developed: the forelegs bear a comb for cleaning the antennæ,

the metatarsi bear a series of spines used as a pollen comb, and the metatibiæ bear a fringe of hairs on the outer surface surrounding what is called the pollen basket, adapted for carrying pollen.

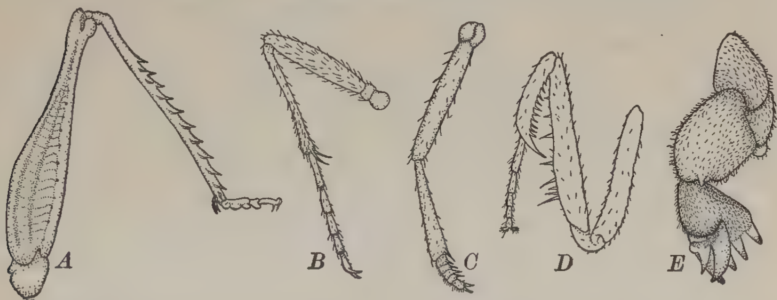

FIG. 25. Types of insect legs

A, grasshopper (*Schistocerca americana*); *B*, a cicindelid beetle (*Cicindela 6-guttata*); *C*, a gyrinid beetle (*Dineutes vittatus*); *D*, a young mantis; *E*, a mole cricket (*Gryllotalpa borealis*)

In aquatic forms the legs are variously developed for swimming or skimming over the surface. The males frequently have the forelegs developed for grasping the females, as in the suckerlike disks on the fore tarsi of the predacious diving beetles (*Dytiscidae*). In general, insects which are strong fliers and are usually on the wing have weak legs.

Wings. Millions of years ago insects became the pioneers in aërial navigation by the development of wings, which have undoubtedly been chiefly responsible for the enormous development of insects as a class, living in all latitudes and environments. The largest existing insects are certain tropical moths whose wings expand nearly a foot, but fossils from the coal age show that immense phasmids (nearly related to grasshoppers) then existed, with a wing expanse of over two feet. The largest wings are not, however, always the most serviceable, and the strongest fliers are usually of medium size. The wings present a variation of structure in almost every group, and, with the

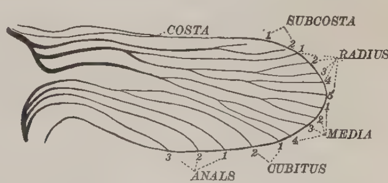

FIG. 26. Hypothetical type of wing venation

(Adapted from Comstock and Needham)

mouth-parts, form the most important basis for classification. Thus most of the orders are distinguished by differences in the wings, as indicated by their names, which usually end in -ptera (from *pteron*, a wing), and many insects may be classified to the genus or even to the species by the wings alone, this being particularly true of fossil forms, in which the wings are often the only parts well preserved.

Most adult insects possess two pairs of wings, borne by the mesothorax and metathorax, but in some parasitic orders the wings have been lost, and one order, the Thysanura, represents the primitive insect without wings. In the flies (Diptera) only the mesothoracic wings are developed, and the metathoracic wings are represented by clublike appendages, called *halteres*, or balancers. The relative shape and size of the two pairs vary greatly, and frequently the two wings of each side overlap or are held together by various structures, so that they act as a single organ. The wings are strengthened by numerous thickenings, called *veins*, whose number and position form the basis of the classification of families, genera, and species. It has been shown by Professors Comstock and Needham that the principal veins are homologous in all the orders of insects, and that they have been derived from one original type, either by the disappearance of certain veins, by their growing together, or by the addition of supplementary veins. The typical longitudinal veins, as shown in Fig. 26, are the *costa*, *subcosta*, *radius*, *media*, *cubitus*, and *anals*. The costa (*c*) is unbranched and strengthens the anterior margin of the wing. The subcosta (*sc*) is typically two-branched, though often single, and, where the costa is small or wanting, appears to be the first, or anterior, vein. The radius (*r*) is typically five-branched, the base of the second principal branch, from which the four posterior branches divide, being known as the *radial sector*. The media (*m*) is typically four-branched, though often but two or three branches are present. Cubitus (*cu*) has

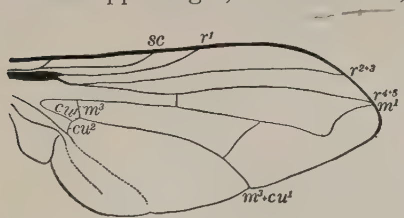

FIG. 27. Wing of house-fly (*Musca domestica*), showing specialization of wing venation through reduction of veins

c, costa; *r*, radius; *m*, media; *cu*, cubitus; *a*, anal. (After Comstock)

usually two branches. The anal veins (*a*) are typically three in number, but often one or two are lost, and in other groups the anal area is greatly expanded and they become many-branched. Specialization by reduction in the number of veins is seen in the wings of the flies, bees, and butterflies and moths, while specialization by addition is found in the wings of Orthoptera and the neuropterous orders.

In several orders the front wings are modified to form wing-covers for the hind wings and are not used in flight. Thus the front wings of the beetles, called *elytra*, are hard and horny, those of the grasshoppers are leathery, and those of the bugs are leathery at the base, with membranous tips.

In addition to being organs of flight, the wings sometimes have other functions. Thus in crickets and other Orthoptera the wings bear sound-producing structures, and the honey-bee maintains the temperature of its hive by the body heat derived from the incessant motion of the wings.

FIG. 28. Wing of May-fly, showing specialization of wing venation by addition of wing veins

Lettering as in Fig. 27. (After Folsom)

Abdomen. The ten segments of the abdomen are the most distinct and simple of the body. The jointed appendages have been almost entirely lost in adult insects, and the abdomen merely houses the respiratory, digestive, and genital systems, the posterior segments being modified in connection with the external sexual organs. In the lowest order, the Thysanura, rudimentary abdominal appendages still exist, and caterpillars and other larvæ frequently bear several pairs of fleshy, unsegmented prolegs, or false legs, bearing a circlet of hooks at the tip. In several orders the females bear an ovipositor, or egg guide, which has been developed from a specialization of the appendages of the seventh, eighth, and ninth segments. The females of many grasshoppers and crickets bear large

ovipositors, with which they are enabled to insert their eggs in the ground or in wood, but the greatest development of the ovipositor is found among hymenopterous insects in which it is formed for sawing, boring, or stinging. Another pair of jointed appendages,

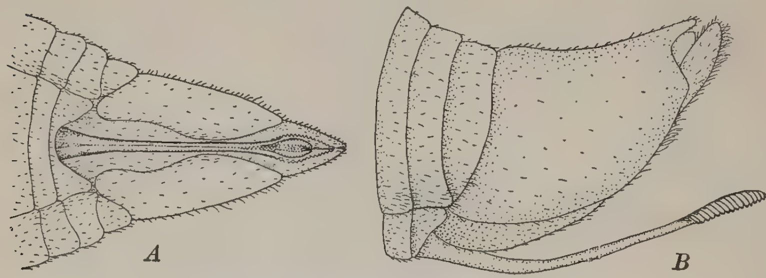

FIG. 29. Ovipositor of periodical cicada

At rest at *A*, and exserted at *B*

called *cerci*, are frequently found attached to the tenth abdominal segment. They are quite variable in length, but in May-flies are as long as the body and resemble very slender antennæ projecting backward from the abdomen. In most cases they are tactile organs, but in the cockroach they assist in smelling.

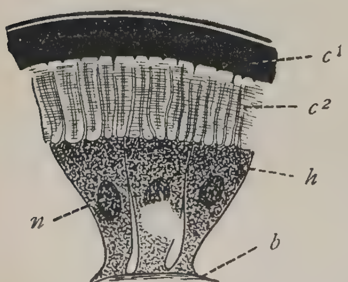

FIG. 30. Section through skin of a beetle (*Chrysobothris*)

b, basement membrane; c^1, primary cuticula; c^2, secondary cuticula; *h*, hypodermis cell; *n*, nucleus. (After Tower, from Folsom)

The number of visible abdominal segments varies from five to eleven in different orders, and frequently the number is different on the upper, or dorsal, and under, or ventral, sides. The structure of the anal segments is usually different in the sexes and furnishes important characters for classification.

Integument. Before studying the internal anatomy, the skin, or integument, of the insect should be considered. This has become hardened so that it forms a firm outer skeleton, to which the muscles and internal organs are attached. Thus the parts of the insect skin, as have been described, are analogous to the bony skeleton

of higher animals in that they support the tissues of the body, and their structure is characteristic of the different groups. This hardening of the skin is found in all arthropods and is due to a substance, called *chitin*, which is formed by the lower layer of cells of the skin, the hypodermis, and which forms an impervious, hard layer over the body of the entire animal, though but slightly developed in the membranous joints between the segments. Chemically, chitin is somewhat akin to silk, or to the spongin of the sponge skeleton. It is unaffected by ordinary acids and alkalies, though soluble in sodic or potassic hypochlorite. The insolubility of chitin is of importance in the consideration of insecticides, for there is hardly anything that can be applied to any but the most soft-bodied insects which will corrode the skin without injuring the foliage of the plants upon which they feed. The surface of the chitinous skin may be smooth or pitted, wrinkled, striated, granulated, or marked in various characteristic ways. The chitin is not only developed by the outer skin but is formed on the surface of the entire epidermis, including the lining of the anterior part of the alimentary tract and the respiratory tubes, or trachea, as can be seen by the examination of a cast skin after an insect has molted.

CHAPTER IV

ANATOMY OF INSECTS — INTERNAL

The general arrangement of the internal organs of an insect may be understood by a study of transverse and longitudinal sections, as shown in Figs. 31 and 32. Attached to the inside of

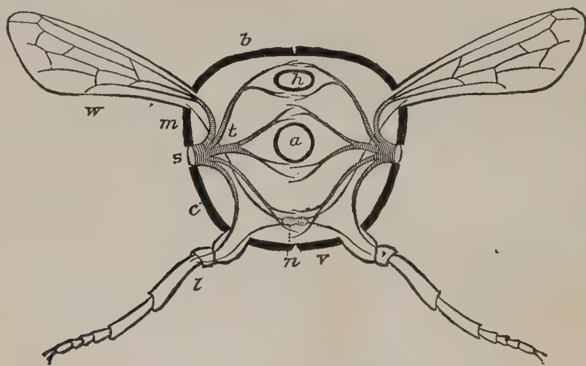

FIG. 31. Ideal section through an insect

a, alimentary canal; *h*, heart; *n*, nerve cord; *s*, stigmata, or spiracles; *t*, tracheal tubes; *l*, legs; *w*, wings. (From Riverside Natural History)

the body wall are found layers of longitudinal and vertical muscles which control the body movements. Through the center of the body runs a large tube, the alimentary canal, or digestive tract.

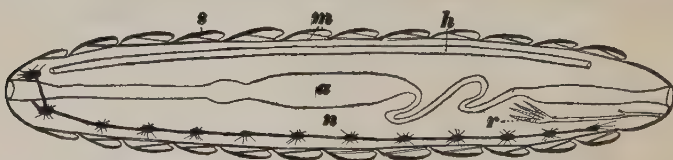

FIG. 32. Ideal longitudinal section of an insect, showing relative position of organs

a, alimentary canal; *h*, heart; *m*, muscle bands; *n*, nerve cord; *r*, reproductive organs. (After Comstock)

Just beneath the back is a small, transparent tube, the dorsal blood vessel, or heart. Along the median line, close to the ventral wall, is a series of small white knots, or *ganglia*, connected by a double

cord, which form the nervous system. On each side of each segment is a small opening through the body wall, called a *spiracle*, through which air is admitted to the breathing tubes, which branch to all parts of the body and form the respiratory system. The reproductive organs are found in the posterior segments of the abdomen and have a separate opening just below the anus.

The digestive system. The digestive tract, or alimentary canal, consists of a more or less straight tube, occupying the larger part of the center of the body and divided into parts with special functions, whose development depends upon the food habits of the insect.

Pharynx. The food, after being torn to pieces and ground up by the mouth-parts, is received into the *pharynx* (often called the

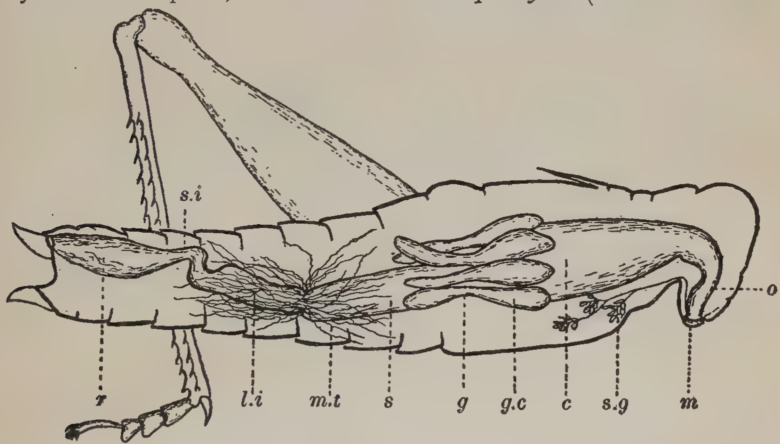

FIG. 33. Digestive and excretory system of a grasshopper

c, crop; *g*, gizzard, or proventriculus concealed by cæca; *g.c*, gastric cæca; *l.i*, large intestine; *m*, mouth; *m.t*, Malpighian tubes; *o*, esophagus; *r*, rectum; *s*, stomach; *s.g*, salivary glands; *s.i*, small intestine

mouth), lying within the head, and in which it is acted upon by the saliva. In sucking insects the pharynx acts as a pumping organ, as already described. The saliva is secreted by the *salivary glands*, which lie along the esophagus in the thorax, whose ducts open at the base of the tongue (hypopharynx). The saliva acts on starch, changing it into glucose as in the vertebrates; in some carnivorous insects it acts on the proteids and is sometimes used to poison the prey; in mosquitoes the poisonous saliva prevents the coagulation of the blood of animals, though its original function may

have been to act on the proteids of plant juices. In most caterpillars, of which the silkworm is the best example, and in many other insect larvæ, certain salivary glands have become specialized so that their secretion hardens upon coming in contact with the air and forms the silk of which their cocoons are spun.

Esophagus. The esophagus is a straight tube passing from the pharynx to the crop or gizzard, or directly into the stomach.

Crop. The crop is practically a dilation of the posterior end of the esophagus and in herbivorous insects forms the larger part of the digestive tract. The food is stored in the crop until the action of the saliva has been completed, changing the starches into glucose sugar and the albuminoids into assimilable, peptonelike substances. In many insects which feed on liquids, the storage capacity of the crop is increased by a lateral pocket, which in some cases forms a separate sac communicating with the crop by a short neck. The walls of the crop contain a layer of muscles which force the food back into the gizzard when it is sufficiently digested.

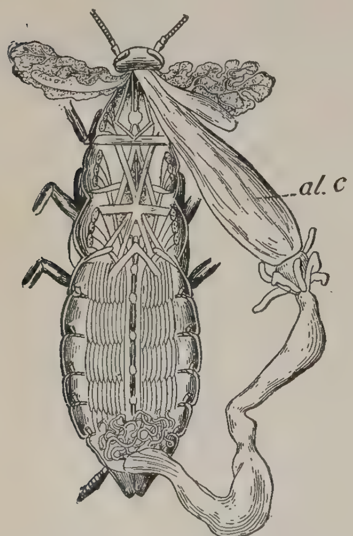

FIG. 34. Cockroach dissected to show alimentary canal and bands of muscles

al.c, alimentary canal. (After Hatshek and Cori, from Jordan and Kellogg)

Gizzard. The gizzard (*proventriculus*) is found best developed in biting insects, such as grasshoppers and beetles, which feed on coarse food, and is but slightly developed or absent in many orders. It is termed "gizzard" because it somewhat resembles the gizzard of a bird and was supposed to function similarly. It is a small, very muscular organ, lined within with strong chitinous teeth, or ridges, which strain the food, preventing the passage of large particles into the true stomach. Some have thought that these ridges aid in grinding the food, but this seems doubtful. Usually a valve allows the food to be forced from the gizzard back into the stomach, but prevents its return.

Stomach. The stomach (*ventriculus*) is usually a simple tube somewhat larger in diameter than the esophagus or intestine, but of variable size and strength. As the food passes into the stomach it is acted upon by the secretions of the *cæcal tubes* (*gastric cæca*) which are glandular pouches, or tubes, opening into the anterior end of the stomach. Their number, size, and shape are quite variable, and they secrete a weak acid which emulsifies fats and converts albuminoids into peptones. The stomach is not lined with chitin, as is the rest of the alimentary tract, but is glandular and secretes a neutral or alkaline fluid which aids in the further digestion of the food. The chief function of the stomach, however, is to absorb the digested food and pass it into circulation.

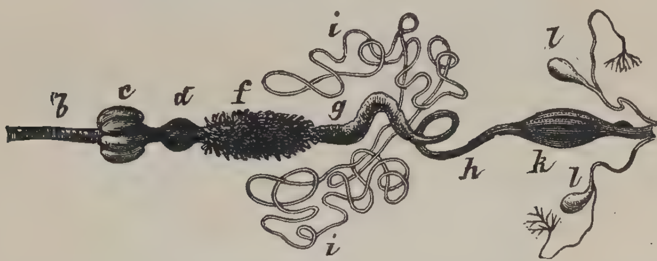

FIG. 35. Digestive canal of a carabid beetle

b, esophagus; *c*, crop; *d*, proventriculus; *f*, stomach with its cæca; *g*, posterior portion of stomach; *h*, intestine; *i*, two pairs of Malpighian tubes; *k*, rectum; *l*, anal glands. (After Dufour)

Intestine. The food passes from the stomach into the intestine through a pyloric valve which prevents its passage backward. The intestine is divided into three fairly distinct parts, the *ileum*, *colon*, and *rectum*. The length and size of these parts varies greatly according to the food of the insect, the ileum often being considerably coiled. In the ileum the digested food materials are absorbed and passed into the blood circulation; the colon, which is often absent, contains undigested matter and waste products; while the rectum has thick, muscular walls and expels the feces through the anus, which opens through the last segment of the abdomen.

Malpighian tubes. Opening into the intestine, just back of the stomach, are several small, slender tubes, variable in number, in which uric acid is found, and which are considered to be excretory organs similar in function to the kidneys of higher animals.

When arsenical insecticides are applied to the food of biting insects, the arsenic must be in the most insoluble form, to avoid burning the foliage, and it is therefore not dissolved until it reaches the stomach, when, having been mixed with the digestive juices mentioned, it becomes sufficiently soluble to be absorbed by the walls of the stomach and ileum. Some insects are able to consume a large amount of poison before an amount sufficient to kill them is dissolved and absorbed. In such cases poisons are sometimes of no avail, because serious injury is done before the pest is brought under control, and other means must be employed.

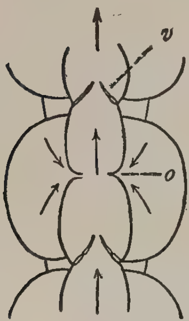

FIG. 36. Diagram of a portion of the heart of a dragon-fly nymph

o, ostium; *v*, valve. The arrows indicate the course of the blood. (After Kolbe, from Folsom)

In the young stages of insects the digestion, and consequent growth, is extremely rapid. A caterpillar will frequently eat and digest two or three times its own weight in a day. Thus the silkworm, when it hatches from the egg, weighs but one twentieth of a grain, but in 56 days, when full grown, it has consumed 120 oak leaves, weighing three fourths of a pound, and half an ounce of water, or 86,000 times its original weight, of which food 207 grains have been assimilated, one fourth of a pound has been voided as excrement, and five ounces have evaporated as water.

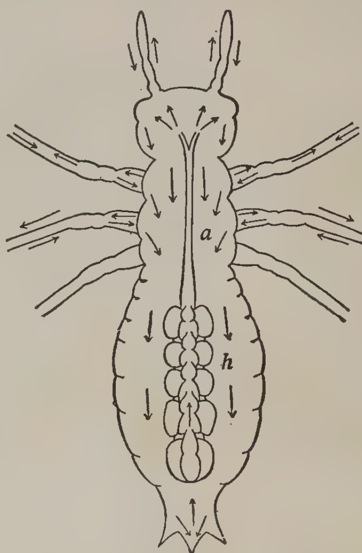

FIG. 37. Diagram to indicate the course of the blood in the nymph of a dragon-fly

a, aorta; *h*, heart. The arrows show the direction taken by currents of blood. (After Kolbe, from Folsom)

Circulatory system. The *blood vessels* of an insect are exceedingly simple, consisting of a single dorsal tube, or heart, which

extends the length of the body along the median line just beneath the notum. In the abdomen of adult insects this tube is divided into several chambers, each of which has a valve at either side, allowing the blood to flow into it but preventing its escape. The chambers are also separated by valves which allow the blood to flow forward but prevent its backward passage. The abdominal part of the tube, the heart proper, pulsates and drives the blood toward the head, while the forward part is a simple blood vessel, called the *aorta*, which usually divides in the head, where it ends abruptly, allowing the blood to flow into the body cavity. Thus the blood is admitted to the heart by the lateral valves, is forced forward to the head, and thence flows in more or less defined currents

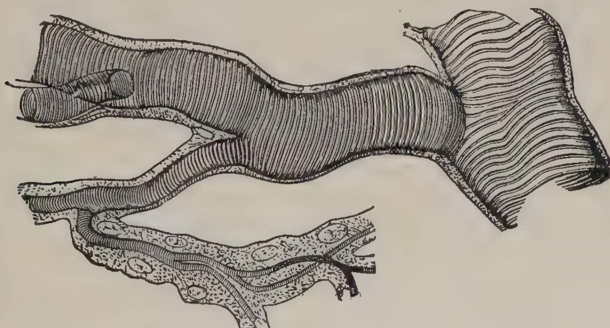

FIG. 38. Portion of a trachea of a caterpillar, with its branches (After Leydig, from Gegenbauer)

throughout the body, bathing all the organs. The pulsation of the heart and the flow of the blood may be observed in many thin-skinned larvæ and nymphs.

The *blood* consists of a watery fluid, — the plasma, or serum, — and the white corpuscles, or leucocytes. Usually colorless, it is often yellowish or greenish. The blood has almost nothing to do with the aëration of the tissues, that being done by the respiratory system, as described below, its chief function being to nourish the tissues with the food materials that it carries.

Respiratory system. Insects have no lungs, but breathe through a system of tubes, called *tracheæ*, which extend to all parts of the body, bringing fresh air to the tissues and carrying off the carbon dioxide. On each side of two thoracic segments, and on all the

abdominal segments but the last two or three are small openings called *spiracles*, or *stigmata*, which are the external openings through which air is admitted to the tracheæ. The spiracles are guarded by hairs and other devices, to prevent the ingress of dust and foreign matter, and each has a valve operated by a special muscle which opens and closes it. From each spiracle a short tube extends inward and opens into a main tracheal tube which extends along the side of the body. There are commonly two of these main tubes, or tracheal trunks, on each side of the body, which give off three main branches in each segment. The upper branch goes to the dorsal muscles, the middle one branches to the alimentary canal and reproductive organs, and the lower one supplies the nerve cord and ventral muscles. These branches divide and subdivide into the finest tubes, which penetrate all the tissues, running between the muscle fibers; some authorities state that they may even enter individual cells. They do not end blindly, but anastomose so as to form a capillary network, so that a continuous circulation of air is possible. By opening the spiracles the air enters the tracheal system, and it is expelled by muscles which cause a vertical contraction of the body walls and thus force it out. The rhythmic expansion and contraction of the body occurs at a regular rate, dependent upon the temperature and the activity of the insect, and resembles the breathing of higher animals. Many insects are provided with large air sacs which serve as air reservoirs. The tracheæ are readily recognized by their striated appearance, which is due to a thickening of the cuticle into a thread, which lies on the inner surface in a compact spiral, like a compressed spiral spring, and thus prevents the collapse of the tubes.

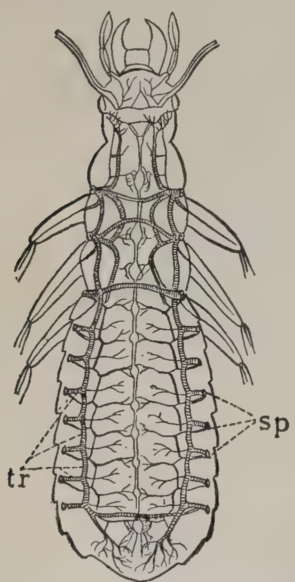

FIG. 39. Diagram of tracheal system in body of a beetle

sp, spiracles; *tr*, trachea. (After Kolbe)

In aquatic insects various respiratory devices have been developed. Many of them (May-fly, dragon-fly, stone-fly, and mosquito nymphs) bear tracheal gills which consist of a leaflike expansion, or a tuft of thin filaments, into which the tracheæ extend and divide into a fine network. The oxygen of the water passes through the gill membrane into the air of the tracheæ, and thus the air of the tracheal system is purified. No true gills, — that is, gills carrying blood vessels, like those of fishes, — are found in insects. Other aquatic insects carry a thin film of air with them, either by means of a thick coating of fine hairs to which air bubbles adhere, or beneath the wing-covers. The tracheæ are sometimes prolonged into tubes which project beyond the tip of the abdomen and extend to the surface of the water or mud in which these insects live.

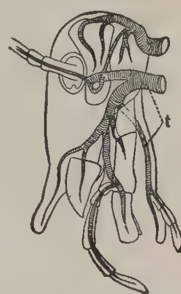

FIG. 40. Diagram of tracheæ in head of cockroach

t, trachea, or air tube. Note branches to all the mouth-parts and the antennæ. (After Miall and Denny)

From the above description it is evident that insects possess the best-developed type of respiratory system, extending as it does to all the tissues of the body, giving them a constant supply of fresh air and carrying off the waste gases. With an ample food supply this makes possible a rapid oxidation of the tissues, and undoubtedly is one of the chief reasons for the wonderful muscular activity, working power, and endurance of insects.

The structure of the respiratory system is of great practical importance in combating insect pests. Many insects which cannot be destroyed with arsenical poisons are killed by contact insecticides in either a spray or a dust form. These contact insecticides destroy the insect by entering or clogging the spiracles or tracheæ. Oils are particularly valuable because they spread and pass readily through the hairs which guard the spiracles. Soap solutions leave a gummy deposit, when the water evaporates, which clogs the tracheæ. Finely divided dusts, such as fine tobacco dust, pyrethrum, and even air-slaked lime or road dust, will clog the spiracles of many insects. Insects living in grain, stored products, and other inaccessible places are often destroyed by the use of poisonous gases, such as carbon bisulphide and hydrocyanic acid gas, which quickly

asphyxiate them through the well-developed tracheal system, though occasionally the valves of the spiracles are so well developed that an insect may keep them closed for a long time, so that fumigation, in order to be fatal, must be prolonged.

Muscular system. Insects are well provided with powerful muscles, a caterpillar having some two thousand. The muscles are yellowish in color, and the fibers are striated as in the voluntary muscles of vertebrates. The simplest type of muscles is found in larvæ and in the abdominal segments of adult insects, where the

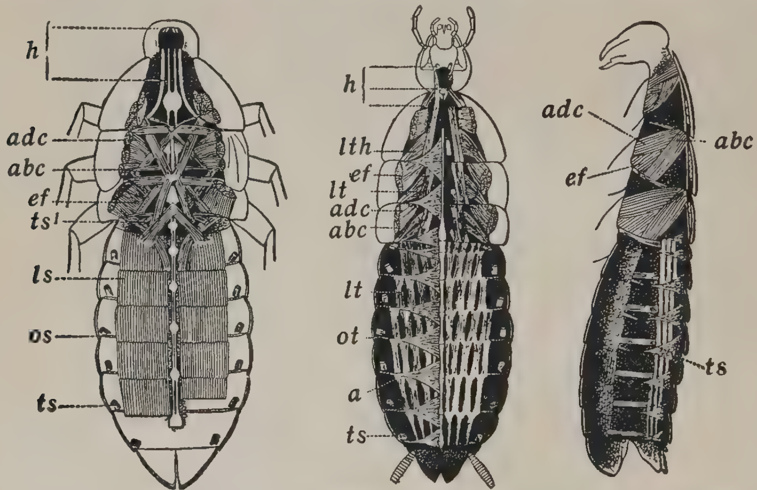

FIG. 41. Muscles of cockroach, of ventral, dorsal, and lateral walls, respectively
a, alary muscle; *abc*, abductor of coxa; *adc*, adductor of coxa; *ls*, longitudinal sternal; *lt*, longitudinal tergal; *lth*, longitudinal thoracic; *os*, oblique sternal; *ts*, tergo-sternal; *ts*¹, first tergo-sternal. (After Miall and Denny)

muscles of each segment are very similar, forming segmented bands on the inside of the body wall. The longitudinal muscles beneath the tergum and above the sternum are arranged so that, when they contract, the body bends in that direction, and by their rhythmic contraction the looping walk of the caterpillar is produced. Oblique-sternal muscles bend the abdomen laterally, and vertical muscles draw the tergum and sternum together in expiration. The thorax of adult insects is filled with the strong muscles which operate the wings and legs, and the muscles which operate the mouth-parts occupy the back of the head.

The work performed by the muscles of insects appears prodigious compared with that done by higher animals. Thus the weakest insect can pull over twenty times its weight. A house-fly can carry a match, to equal which a man would need to carry a timber thirty-five feet long and as large around as his body. An earwig can lift twelve times its weight, and a honey-bee, in flight, carries four fifths of its weight. A small insect is relatively stronger than a large one, and the relative strength of insects is largely accounted for by their small size. This is due to the fact that the weight increases as the cube of a single dimension, while the strength of a muscle increases as the square of its diameter. The endurance and rapidity of muscular action of insects is no less marvelous. By determining the pitch of the note made by the wing vibrations of a gnat, physicists have shown that its wings may move as many as fifteen thousand times per minute. The prolonged vibration of the honey-bee's wings is another instance of remarkable muscular endurance.

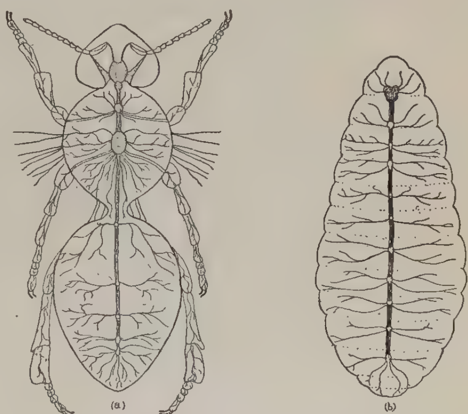

FIG. 42. Nervous system of honey-bee, at *a*, and of its larva, at *b*, showing the simple type of the larva and the specialization in the adult due to fusion of the ganglia

Nervous system. The nervous system consists of a series of small white ganglia which are connected by a double nerve cord lying along the bottom of the body cavity. In the larvæ there is usually one ganglion to each segment, but in the adult insects the ganglia are often fused together, those of the thorax and anterior abdominal segments having grown together, as well as those toward the tip of the abdomen. In the head the ganglia have grown together to form the brain, which lies just above the esophagus and which is connected with the subesophageal ganglion by a double nerve cord, one commissure of which passes on either side

of the esophagus, thus forming a nerve collar. The brain gives off nerves to the eyes, antennæ, palpi, and other sensory organs of the head, receiving the sensory stimuli and controlling the coördinated muscular movements. In a general way the brain is the seat of whatever "will" an insect may have. The subesophageal ganglion coördinates the movements of the mouth-parts, as well as some bodily movements. The thoracic and abdominal ganglia give off nerves to all parts of their segments, the movements of which they control. They are more or less independent, each

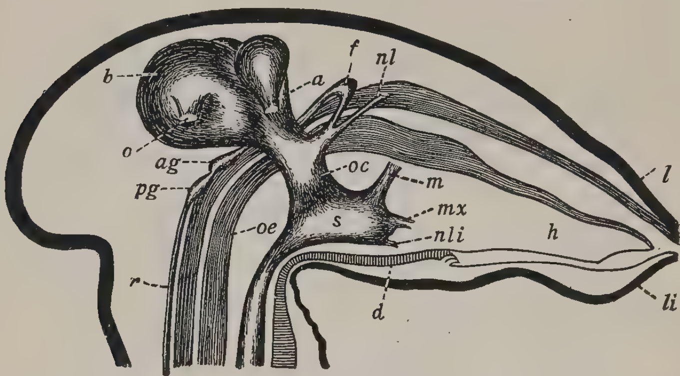

FIG. 43. Nervous system of head of cockroach

a, antennal nerve; *ag*, anterior lateral ganglion of sympathetic system; *b*, brain; *d*, salivary duct; *f*, frontal ganglion; *h*, hypopharynx; *l*, labrum; *li*, labium; *m*, mandibular nerve; *mx*, maxillary nerve; *nl*, nerve to labrum; *nli*, nerve to labium; *o*, optic nerve; *oc*, esophageal commissure; *oe*, esophagus; *pg*, posterior lateral ganglion of sympathetic system; *r*, recurrent nerve of sympathetic system; *s*, subesophageal ganglion. (After Hofer, from Folsom)

forming a nerve center for its segment. Thus a decapitated insect will walk or fly, and the abdomen of a grasshopper will continue to breathe, these functions being controlled by the segmental ganglia, though lacking coördination. In addition to the main nervous system there is a *sympathetic system*, one part of which runs along the upper part of the alimentary canal and controls the digestive process, while a small ventral sympathetic nerve gives off branches which control the spiracle muscles.

Dr. J. B. Smith, in his "Economic Entomology," gives an interesting account of some experiments which show the relation of the brain and ganglia to the body:

I found that if I cut off the abdomen completely, the fly would live for twenty-four hours thereafter; with practically no digestive system, and with most of its heart gone. Turning the matter, I cut off the head, and found that it would live without a head for just about as long a time as it would without an abdomen. Of course death was bound to result from this mutilation in time, but the interesting feature is that no apparent symptom of pain developed. I found, however, that just as soon as I cut the large ganglion in the middle of the thorax I terminated life. Whatever sentimental feeling there may be in the matter of causing unnecessary pain, there is no reason to believe that insects have any well-developed sensitiveness, as we understand that term. The character of the insect nervous system is so entirely different from that of our own that we are left without real guides in our interpretation of the various sensitive structures. Man judges most things by himself, and where this guide fails, he is at a loss and cannot be certain that he interprets what he sees correctly.

The senses of insects. *Sight.* Attention has already been called to the simple eyes, or ocelli, and the compound eyes. An ocellus consists of a lens, vitreous body, retina, and nerve, much like the eye of vertebrates, but its form is fixed, and as there is therefore no power of accommodation to the distance between it and the object seen, its power of vision must be extremely limited. As far as the ocelli are concerned, insects must be very nearsighted, for they are quite convex and will only focus at one distance, which must be short. Experiments have shown that light and darkness are distinguished by the ocelli, for if the compound eyes of a grasshopper are covered with varnish, it can find its way out of a box with a single opening. Probably the ocelli are of more service in this way than in forming definite images, though insect larvæ possess only ocelli.

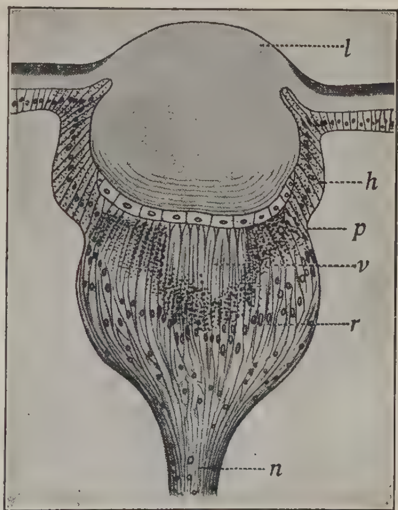

FIG. 44. Structure of median ocellus of honey-bee, in sagittal section

h, hypodermis; *l*, lens; *n*, nerve; *p*, iris pigment; *r*, retinal cells; *v*, vitreous body. (After Redikorzew, from Folsom)

The surface of the compound eye is composed of numerous hexagonal facets, each of which is the end of a single eye element called an ommatidium, which is practically a separate and distinct eye. Each ommatidium is composed of the various optical elements necessary for vision, but it receives impressions only in a straight line, which form only a very small part of the total field of the insect's vision. This is due to the fact that each ommatidium is surrounded by black pigmented cells, which absorb or reflect the light, as shown in Fig. 46, so that only those rays which come in a straight line impress the retina. Thus the whole view formed by the images from all the ommatidia as they reach the optic nerve must be like that of a mosaic.

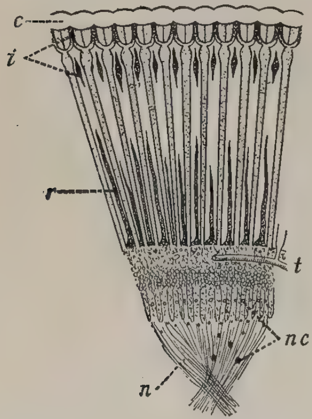

FIG. 45. Portion of compound eye of fly (*Calliphora vomitoria*), radial section

c, cornea; *i*, iris pigment; *n*, nerve fibers; *nc*, nerve cells; *r*, retinal pigment; *t*, trachea. (After Hickson, from Folsom)

Insects are able to distinguish forms at but relatively short distances, varying from two to five feet, and to see distinctly only near-by objects. Large eyes, as those of the dragonfly, give a wide field of vision, and numerous facets would give a greater distinctness of vision. Insects' eyes are well adapted to detect motion, as a moving object affects the facets in succession, and motion is thus observed without moving the eyes. They are able to distinguish colors and often respond quite definitely to them, but their color sense seems to have a different range from that of man, as ants are sensible to the ultra-violet rays.

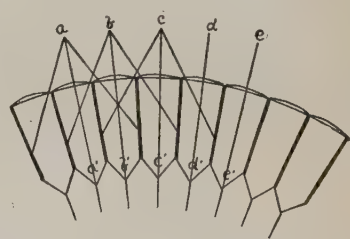

FIG. 46. Illustrating mode of vision in compound eye

"The light enters through the cornea. The rays which strike the sides of each tube or cone are absorbed by the black pigment which surrounds the tube. Accordingly those rays of light only which pass through the crystalline cones directly (or are reflected from their sides), such as *a-a′*, *b-b′*, *c-c′*, *d-d′*, *e-e′*, will ever affect the nerves at *a′*, *b′*, *c′*, *d′*, *e′*." (After Lubbock, from S. J. Hunter)

Touch. The sense of touch is very highly developed in many insects, sensory tactile hairs commonly occurring over the whole body, and the antennæ, palpi, and cerci being specially developed as tactile organs.

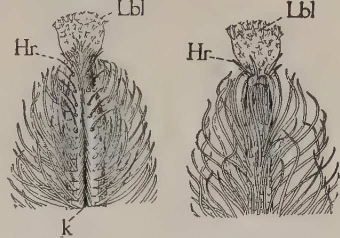

FIG. 47. Tip of tongue of honey-bee

Showing labellum (*Lbl*), guard hairs (*Hr*), and ventral groove (*k*), from above and below. (After Snodgrass, United States Department of Agriculture)

Taste. Both observation and experiment have shown that insects have a well-developed sense of taste, though it is often quite different from that of man, as they detect some substances but fail to perceive others, and often seem to relish substances wholly repugnant to us. The sense of taste is located in sensory hairs or microscopic pegs borne upon the tongue (see Fig. 47), or hypopharynx, on the epipharynx (a

FIG. 48. Nerve endings in tip of maxillary palpus of (*a*) *Locusta viridissima*, and in labial palpus of (*b*) *Machilis polypoda*. (Greatly magnified)

sh, sense hairs; *sc*, sense cells; *bc*, blood cells. (After Vom Rath, from Kellogg)

sensory portion of the roof of the pharynx similar to the palate of higher animals), and on the maxillary and labial palpi. Probably the sense of smell is used more than the sense of taste in choosing food.

Smell. Most insects depend upon their sense of smell to find their food and to discover the opposite sex. Thus beetles and flies are drawn to carrion and to decaying vegetation, and in almost all cases it seems probable that the food plant of an insect is distinguished by smell rather than by sight. A confined female Cecropia moth will often draw numerous males from a considerable distance. Experiments have shown that the antennæ are the chief organs of smell, though the maxillary palpi and cerci detect certain odors and enable certain insects to smell when the antennæ are removed. The olfactory function of the antennæ can be very easily shown by taking an insect which is definitely attracted to some substance by smell and removing the antennæ or covering them with shellac, when it will be found wholly indifferent to what was previously so attractive. Vile-smelling substances which are supposed to repel insects are usually of no value, not affecting the insect as they do man. Some attempts have been made to utilize the sense of smell in luring insects to destruction, but as yet with no very marked success, though there is promise of possible control of some pests in this way.

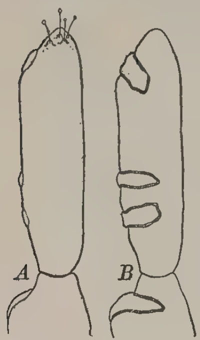

FIG. 49. Sensory cells in antennæ of aphides. (Greatly magnified)

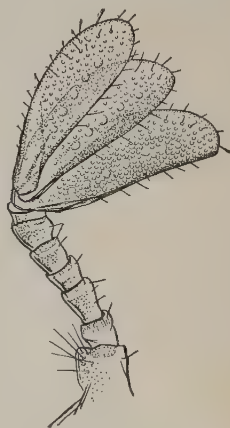

FIG. 50. Antenna of lamellicorn beetle

Showing smelling pits on the expanded terminal segments. (After Jordan and Kellogg)

FIG. 51. Under surface of right wing of the male cricket. (Enlarged)

1, rasp; *2*, position of scraper, only scraper of the left wing used; *3*, attachment of wing. (After Linville and Kelly)

Hearing. There is no evidence that hearing is generally developed in insects, but in many groups we naturally infer its presence from the fact that characteristic noises are produced, as the "singing" of the cicada and katydid. These noises are produced in various

ways. Thus flies and bees buzz with their wings in rapid vibration, and the singing of the male cicada is produced by the rapid vibration of a pair of membranes on the first abdominal segment. Many beetles squeak by rubbing the wing-covers against some rasp-like part of the body. But the grasshoppers and crickets are the leaders in the insect orchestra. Grasshoppers often produce noises in flying by rubbing the hind legs against the wing-covers or by rubbing together the front and hind wings. Katydids and crickets have the best-developed musical apparatus, having a scraper on the base of one wing-cover and a vein ridged like a file on the base of the other, which, when rubbed together, vibrate the neighboring membrane and produce the strident song, or the shrill chirp, so characteristic of these insects.

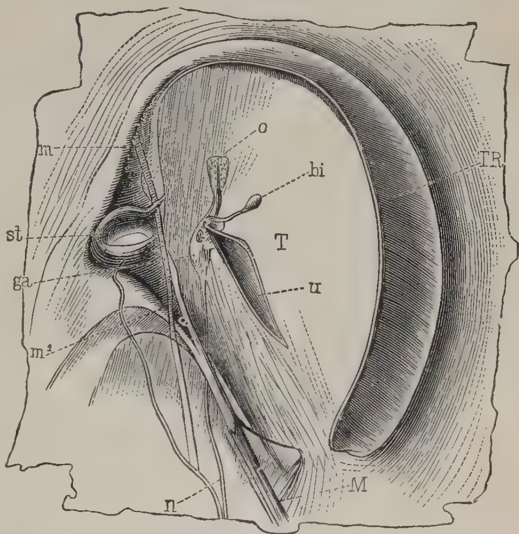

FIG. 52. Ear of locust (*Caloptenus italicus*) seen from the inner side

T, tympanum; *TR*, its border; *o*, *u*, two bonelike processes; *bi*, pear-shaped vesicle; *n*, auditory nerve; *ga*, terminal ganglion; *st*, stigma, or spiracle; *m*, opening muscle, and m^1, closing muscle of same; *M*, tensor muscle of the tympanic membrane. (After Graber)

That these sounds are heard by their mates is shown by the answering call of one to another, and to similar tones produced artificially. In grasshoppers a large auditory organ, or "ear," is found on either side of the first abdominal segment. It consists of a surface membrane, or tympanum, stretched over a cavity, on the inner surface of which rest two processes, analogous to the small bones of the human ear, which carry the vibration to a delicate vesicle which connects with an auditory nerve. Similar small membranes are found on the fore-tibia of certain insects and are

considered probably auditory. In male mosquitoes, and probably in some other forms, the antennae have an auditory function which enables them to find the females, as is shown by their vibrating in unison with a tone produced by a tuning fork of the same pitch as that made by the female with her wings.

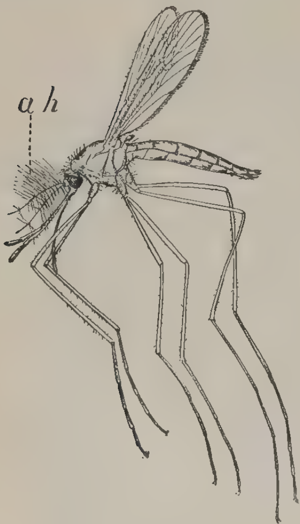

FIG. 53. Male mosquito

Showing auditory hairs (*ah*) on the antennæ. (After Jordan and Kellogg)

FIG. 54. Diagram of longitudinal section through first and second antennal segments of a mosquito (*Mochlonyx culiciformis*), male, showing complex auditory organ composed of fine, chitinous rods, nerve fibers, and nerve cells. (Greatly magnified)

(After Child, from Kellogg)

CHAPTER V

THE GROWTH AND TRANSFORMATIONS OF INSECTS

Stories of the lives of insects, or their "life histories," are among the most interesting and marvelous to be found in the realm of science, furnishing themes for poet, philosopher, and scientist.

Egg. All begin life in the egg stage. The shape, size, number, and position of the eggs are as different as are the many families of insects, and cannot be described in general terms. Usually they

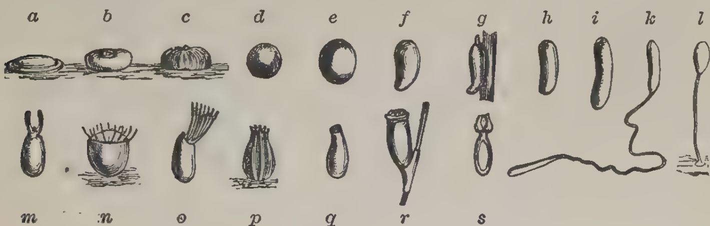

FIG. 55. Eggs of different insects. (Enlarged)

a, *Tortrix*; *b*, *Liparis*; *c*, a Noctuid; *d*, usual shape of those of a bark borer; *e*, May-beetle (*Lachnosterna*); *f*, midge (*Chironomus*); *g*, *Lyda*; *h*, fly (*Musca*); *i*, honey-bee; *k*, gall-fly (*Rhodites rosae*); *l*, lace-winged fly (*Chrysopa*); *m*, pomace-fly (*Drosophila*); *n*, *Pentatoma*; *o*, back-swimmer (*Nepa*); *p*, butterfly (*Pieris crataegi*); *q*, bedbug; *r*, louse, fastened to a hair; *s*, bot-fly (*Hypoderma*). (After Judeich and Nitsche, from Packard)

are laid upon the food plant, or host, but occasionally their position could not be accounted for were the habits of the young not known. The number laid by a female may vary from one or two, as in the case of some aphides, to many thousands, as in bees and termites, but a fair average would probably be about one hundred. The size varies inversely with the number produced, and the shape and structure are largely influenced by the environment in which the eggs are laid. In a few cases the eggs hatch within the body of the female, which thus gives birth to live young, as do the aphides. Those eggs which hatch during the summer have an incubation period of from a day or two, as do those of certain flies and mosquitoes, to

three or four weeks, while very many remain dormant over winter and hatch when sufficient temperature occurs the next spring or summer.

Transformations. Upon hatching from the egg the young grasshopper is of much the same general appearance as when full grown, and is readily recognized as a grasshopper; but if we did not

FIG. 56. Molting of the full-grown nymph of the periodical cicada, showing process of emerging from the skin of the nymph, with the soft white adults below

The adults become black after hardening for a few hours

know that the little caterpillar, after completing its growth, finally transforms into a butterfly, we should never suspect them to be different stages of the same insect, and a lack of knowledge of these transformations has caused many strange superstitions concerning insects.

The transformation of the butterfly from the caterpillar is a *complete* one, and is known as a *complete metamorphosis*. The

growth of the grasshopper, on the other hand, is gradual and presents no striking changes, and is known as an *incomplete metamorphosis*.

Growth. The hard, chitinous skin which serves the insect as an outer skeleton has already been described, and furnishes an obvious obstacle to its rapid growth. When the insect has grown to the limit of this outer shell, its predicament is solved in the only possible way, by the skin splitting down the middle of the back and being sloughed off, while the new skin formed beneath the old one allows further growth. This process, called molting, occurs in all insects, as well as among other Arthropods, the skin being usually shed some four or five times during growth, though some species molt from ten to twenty times.

FIG. 57. Nymph of lubber grasshopper (*Dictyophora reticulata*); similar to the adult (Fig. 103) in general form, except in lacking wings

Incomplete metamorphosis. Young insects which resemble the adults, as those of the grasshopper, are termed *nymphs*. After the second or third molt, small wing pads appear on the back, becoming much larger with the fourth molt, and upon the fifth molt the adult winged insect emerges, to feed and reproduce.

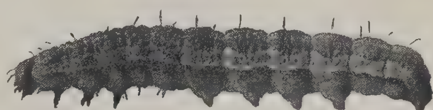

FIG. 58. A typical larva, the cotton bollworm or corn-ear worm; totally unlike the adult moth in form

Complete metamorphosis. The caterpillar, maggot, or grub bearing no resemblance to its parents is called a *larva*. The larva grows and molts several times, and although its new clothes are sometimes of a different color, they are all cut on the same pattern, and there is usually no marked change in shape or structure until the larva is full grown. Upon reaching its growth the larva molts for the last time and transforms into a *pupa*. The pupa is a dormant

stage, usually inactive and taking no food, resembling neither larva nor adult, in which the tissues and organs of the larva are reconstructed into those necessary for the winged adult. In many pupæ the wings and legs of the adult are clearly distinguishable, closely folded to the sides of body, but in the others the outer skin of the pupa is only a firm shell with bare outlines of the adult forming within.

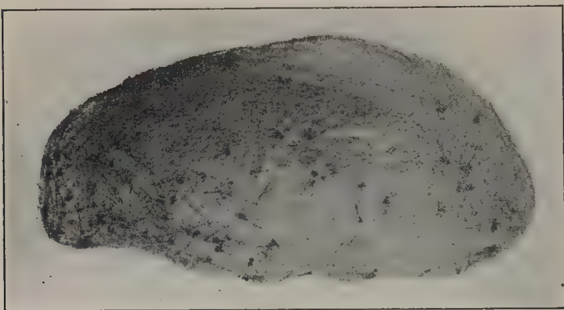

Fig. 59. Cocoon of the rusty tussock moth, made of silk with the hairs of the caterpillar intermingled. (Enlarged)

Before the last molt many larvæ burrow into the ground, where they hollow out cells, sometimes lined with silk or cement, or find other suitable secluded places in which to pupate. The caterpillars of moths and many other larvæ spin a firm casing of silk, called a *cocoon*, in which they pupate. Butterfly caterpillars lash themselves to the food plant by one or two thick strands of silk, and the pupa, which is known as a *chrysalis*, hangs suspended by the tip of the abdomen with no cocoon. In many cases insects hibernate over winter in the pupal stage, so that the time of the pupal life varies from a few days in summer to nine or ten months, according to the habit of the species. Finally, the pupal shell splits open and

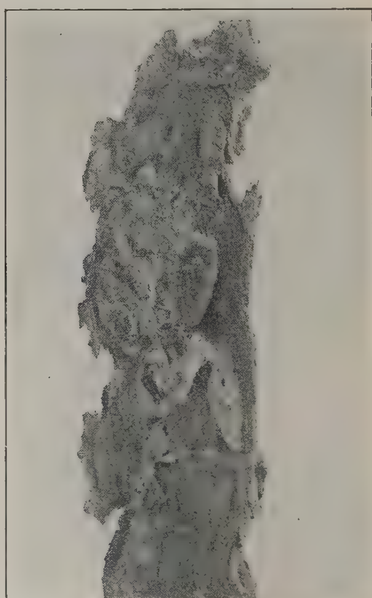

Fig. 60. Cocoons of tiger moth caterpillars on underside of loose bark

the adult insect emerges, with wings soft and limp but expanding and hardening in a few hours, when it is ready to seek food and a mate.

Thus the stages of growth of those insects having a complete metamorphosis are essentially different from those having the incomplete type, as indicated in the following summary:

Incomplete metamorphosis:	Egg,		Nymph,	Adult.
Complete metamorphosis:	Egg,	Larva,	Pupa,	Adult.

An insect never grows after it reaches the adult stage. The little flies which appear on the window in early spring are not "baby" flies and do not grow larger, but are entirely different from other larger species which supersede them later in the season.

The life histories of insects are as diverse as are the species, no two being quite alike. To study and carefully determine the time, place, and manner of the transformations is one of the most important duties of the economic entomologist, for by ascertaining them the means of control of injurious species are often discovered. Many insects may thus be controlled by simply changing general farm methods, such as the rotation of crops, the time of plowing, etc., which result in the prevention or mitigation of the pest; or a knowledge of the feeding habits may indicate the most promising means of attack, and successful methods may be determined by subsequent experiments.

FIG. 61. Chrysalis of black swallow-tailed butterfly (*Papilio polyxenes*)

Showing attachment of tip of abdomen to mass of silk threads which have become torn from around the stem, and the silken loop which supports the thorax. (Photograph by Weed)

A better appreciation of these general facts concerning insects' growth will be secured by a more intimate study of the life of one or two of each of the types of metamorphosis.

The life of a squash-bug (*Anasa tristis*). Incomplete metamorphosis. About the time that squash, cucumbers, and melon vines begin to "run," there is found here and there a wilted leaf, which examination shows to be due to the common grayish- or brownish-black squash-bug which has just emerged from hibernation. If search be made in the early morning, the bugs will usually be found secreted under clods of earth, or whatever rubbish may be near the vines, from which they emerge to feed during the day, flying about with a characteristic buzz.

FIG. 62. The squash-bug, adult and nymphs of first, third, and fifth stages. (About twice natural size)

(Photograph by Quaintance)

Egg. For the next month or six weeks the females deposit their eggs, mostly on the undersides of the leaves. The eggs are oval, about one sixteenth inch long, attached on one side, and laid in irregular-shaped clusters arranged in rows as shown in Fig. 63, from three or four to forty eggs being found in a cluster. Newly laid eggs are a pale yellow-brown, which grows darker a day or two before hatching, so that the approximate development may be determined by the color, which is the case with many insects' eggs.

Nymph. In about eleven days, the exact time varying from six to fifteen days according to the temperature, a small, disk-shaped piece of the shell is forced open toward one end of the egg and the little nymph emerges. The newborn buglet is brilliantly colored and is quite conspicuous against the green leaves, the antennæ and legs being a bright crimson, the head and anterior thorax a

lighter crimson, and the posterior thorax and abdomen a bright green; but in an hour the crimson darkens, and in a few hours changes to a jet-black. The young bugs hatching from a cluster of eggs remain together in a sort of family during their infancy, each inserting its tiny beak in the succulent leaf from which it vigorously sucks the juice. In about three days the abdomen becomes distended, indicating the need of a larger suit of clothes to allow further growth. The nymph now assumes a quiet position, the skin splits down the middle of the back along the thorax and anterior abdomen, and gradually the little bug pulls itself out of its baby clothes, the time required for this change of costume varying from a half-hour to several hours.. A few hours later the skin, now much lighter in color, has hardened, and the insect is about one fifth inch long. The nymph now becomes more active and alert and continues to feed some nine days before molting again. In the third stage it is considerably larger and flatter, and darker in color. Eight days later the third molt takes place, and the new clothes of the fourth stage differ in having small but distinct wing pads extending back

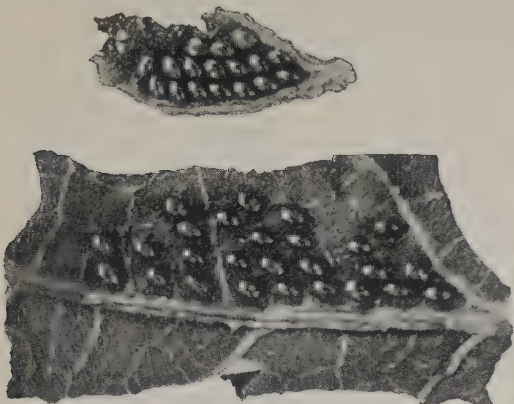

FIG. 63. Egg masses of squash-bug. (Twice natural size) (Photograph by R. I. Smith)

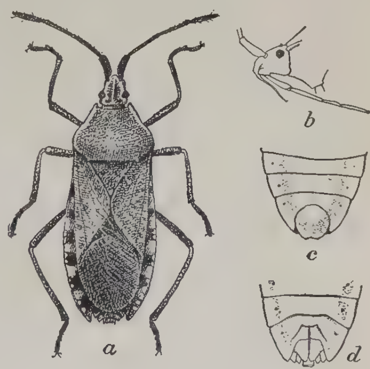

FIG. 64. Squash-bug

a, mature female; *b*, side view of head, showing beak; *c*, abdominal segments of male; *d*, same of female. (*a*, twice natural size; *b*, *c*, *d*, more enlarged.) (After Chittenden, United States Department of Agriculture)

FIG. 65. Squash-bugs and nymphs at work on a young plant. (Natural size)

from the thorax. In another week the skin is shed for a fourth time, and the fifth stage is easily recognized as a full-grown nymph, being one third inch long, and the wing pads and thorax being much enlarged. After feeding for another nine days it molts for the last time and transforms to the winged adult, the whole growth having required from four to five weeks.

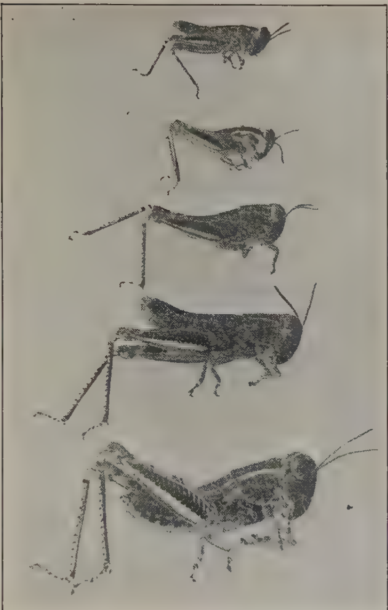

FIG. 66. First three stages of the nymphs of the differential locust. (Much enlarged)

Adult. The new adults become numerous in August, but neither mate nor lay any eggs during that season, continuing to feed until the first frosts of autumn blacken the leaves, when they rapidly disappear into winter quarters.[1] During the middle of the day they fly here and there in search of suitable hibernating places, and finally hide along the edges of woodlands, or beneath leaves, under logs, boards, or whatever shelter may be adjacent to the garden, where they remain dormant until called back to activity by the warm sunshine of late spring.

Life history of the differential locust (*Melanoplus differentialis*). Incomplete metamorphosis. Throughout the Mississippi Valley, from Illinois southward, the differential locust is one of the most common and destructive grasshoppers, and is an excellent example of several of our more abundant and injurious species whose life histories and feeding habits are, in general, very similar.

FIG. 67. Egg mass of the differential locust

[1] The life history as given is for New England; farther south the transformations take place earlier and more rapidly, and in the extreme south there may be more than one generation.

Nymphs. The little grasshoppers hatch about the middle of May (though we have observed hatching by the middle of March in central Texas) and are of a dusky brown color marked with yellow. The head and legs are the most prominent features of the young nymph. During their subsequent growth they molt five times, at intervals of from ten days to two weeks, the relative size and appearance of the different stages being shown in Figs. 66, 68. Professor H. A. Morgan, who made a careful study of an outbreak of this species in Mississippi in 1900, has given an interesting account of their growth and habits, from which the following is quoted:

FIG. 68. Last two stages of nymphs of differential locust. (Enlarged)

Growth. The young on first emerging from the eggs are sordid white and after an airing of an hour or two are darker, assuming a color not unlike the dark gray alluvial soil over which they feed. There are changes of color as the earlier stages are assumed, but until the close of the third stage these changes are not readily perceptible in the field to the naked eye. At the close of stage four the greenish-yellow color becomes prominent on many forms, and in stage five the greenish-yellow and yellow ground colors predominate. The vigorous feeding and rapid growth of the young in stages four and five, and the prominence of the wing pads in stage five, cause the grasshoppers in these conditions to appear almost as conspicuous as adults.

Habits. The habits of the young are interesting, and a knowledge of some of them may be helpful in developing remedies. After hatching they remain for several hours in close proximity to the egg pod from which they emerged. With this period of faint-heartedness over they may venture out for a few yards each day into the grass, weeds, or crop neighboring the egg area. Upon being disturbed they invariably make the effort to hop in the direction of their so-called nest. Nymphs emerging from eggs on a ditch bank, if forced into the water will seldom make the effort to reach the other side, but will turn back to the bank from which they were driven. As development takes place the extent

of their peregrinations into the crop is easily traced by the shot-hole appearance of the leaves upon which they feed. The tender leaves of cocklebur are always preferred by the grasshoppers in the early stages. Young Bermuda grass is also a favorite food, and succulent grasses of all kinds are freely eaten. In the third, fourth, and fifth stages, as grass, weeds, and even shrubs disappear along the ditch banks and bayous, the crops of corn and cotton adjacent begin to show signs of vigorous attack, and the march of destruction commences. . . . A few hours before molting the grasshoppers tend to congregate and become sluggish. Molting varies as to time, and slightly as to manner, with different stages. In the early stages less time is required, and the operation occurs on the ground or upon low bunches of grass and weeds. Every effort of the grasshoppers at this time seems to be to avoid conspicuity, and in doing so spare themselves, in a manner, enmity of parasites. After the molting of the first, second, and third stages it is not long before the young grasshoppers are sufficiently hardened to begin feeding again, but after the molt of the fourth and fifth stages, particularly the last molt, some time is required to extend the wings and dry and harden the body before feeding is reassumed. The last molt usually occurs on the upper and well-exposed leaves of corn and other plants upon which they may be feeding, though it is not uncommon for the grasshoppers to drop to the ground during the maneuvers of the process. The reason for the selection of the more exposed places for the last molt is obvious. The bodies are large, and rapid drying protects them from fungous diseases which lurk in the more shaded and moist sections during the months of June and July. The last prominent habit to which we call attention is that of the fully grown grasshoppers to seek the shade offered by the growing plants during the hottest part of the day.

FIG. 69. Nymph of last stage of differential locust with cast skin, on tip of corn plant

(Authors' illustration, United States Department of Agriculture)

Adults. The hoppers become full grown about the first of July. The adult is about one and one half inches long, its wings expand two and one half inches, and it is of a bright yellowish-green color.

FIG. 70. The differential locust. (Enlarged)
(Authors' illustration, United States Department of Agriculture)

The head and thorax are olive-brown, and the fore-wings are of much the same color, without other markings than a brownish shade at the base; the hind-wings are tinged with green; the hind thighs are bright yellow, especially below, with four black marks; the hind shanks are yellow with black spines and a ring of the same color near the base. The adults at once attack any crops available, often finishing the destruction of those injured by them as nymphs, but in a few days their appetites seem to become somewhat appeased and they commence to mate and to wander in search of suitable places for laying the eggs.

FIG. 71. Grasshopper ovipositing in a stump
(Photograph by Weed)

Egg laying. Relatively few eggs are laid in cultivated ground, the favorite places being neglected fields grown up in grass and weeds, the edges of

cultivated fields, private roadways, banks of ditches and small streams, and pasture lands. Alfalfa land is a favorite place for oviposition, and alfalfa is often seriously injured by this species. It is doubtless due to these egg-laying habits, and to the abundance of food on uncultivated land, that this species always increases enormously on land which has been flooded and then lies idle for a year or two. Most of the eggs are laid in August and early September. Each female deposits a single egg mass of about one hundred eggs just beneath the surface of the soil. During this season the females may frequently be found with their abdomens thrust deep in the soil, as the process of egg laying requires some time. The eggs are arranged in an irregular yellow mass which is coated with a gluey substance, to which the earth adheres and which protects them from changes of moisture and temperature.

FIG. 72. Egg mass of the tent caterpillar

(Photograph by Weed)

Life history of the tent caterpillar (*Malacosoma americana*). Complete metamorphosis. With the bursting of the leaf buds in early spring the tips of the branches of apple and wild cherry trees are festooned by the small, tentlike webs of the tent caterpillar. Usually the web is formed on a small crotch, which gives it the tent shape, and farther out on the twig will be found the egg mass from which the little caterpillars hatched, just before the leaf buds opened.

FIG. 73. Web of young tent caterpillars over the egg mass

(Photograph by Weed)

The egg mass is from one half to three fourths of an inch long and forms a grayish-brown, knotlike band around the twig, closely resembling the bark in color. Each mass contains from one hundred fifty to two hundred fifty eggs, placed on end, packed closely together, and covered with a layer of light brown, frothy glue, which gives a tough, smooth, glistening surface to the whole mass. The eggs are deposited by the female moths by early midsummer; when fresh the egg mass is white, but in a few days the color darkens.

FIG. 74. Partly formed web of the tent caterpillar

(Photograph by Weed)

Larva, or caterpillar. During late summer the little caterpillars are formed within the eggs, but do not hatch until the next spring. Often they emerge before the leaf buds have expanded sufficiently to furnish any food, in which case they satisfy their appetites with the glutinous covering of the egg mass, spinning over it a thin web. Soon they are able to bore into the swollen buds, when a web is commenced at the nearest crotch. Wild cherry and apple, which are often stripped of their foliage year after year, are the favorite foods, but all the common fruit trees are more or less frequented, and sometimes the common shade trees are attacked and occasionally one is defoliated. The family instinct is very strong with the young caterpillars and all from one egg mass coöperate in spinning the tent which furnishes them shelter at night and during cold or wet weather. The tent is gradually enlarged by new layers of silk, which cover the masses of excreta in the lower layers, the caterpillars living between the outer layers. They commence feeding soon after sunrise, but often retire to the nest during the heat of the day, and always seek its shelter during cold days or

FIG. 75. Tent caterpillars about half grown on web

(Photograph by Weed)

when the sky becomes clouded and rain threatens. While young they feed together, each little caterpillar spinning a fine strand of silk wherever it goes, which forms a sort of trail for the others. They become full grown in six or seven weeks, during which time they have molted some four or, exceptionally, five times, at intervals of eight or nine days, though the length of time between molts varies widely according to the food supply and weather conditions. After the fourth molt the fifth stage occupies about two weeks before the caterpillar transforms to the pupa. When full grown they become extremely restless, wander away from the nest, and are frequently encountered on walks and roadsides, and feed on almost any plant found. They are now about two inches in length, deep black in color, thinly covered with yellowish hairs, with a white stripe down the middle of the back. At the middle of the side of

FIG. 76. Full-grown tent caterpillars on web. (Reduced)

(Photograph by Weed)

each segment is an oval, pale blue spot with a broader, velvety black spot adjoining it in front, giving somewhat the effect of an eyespot.

Cocoon and pupa. Having found a suitable place under loose bark, in a fence, in the grass or rubbish beneath the tree, or in the shelter of some neighboring building, the caterpillar settles down and proceeds to encase itself in a thin cocoon of tough white silk. In forming the cocoon the caterpillar rolls its head from side to side, the silk being drawn out from the lower lip and hardening as soon as it comes into contact with the air. With wonderful contortions it gradually shapes the oval cocoon, the outer part of which is composed of coarse, loose white threads, with a yellowish powder intermixed, while the inner layer forms a tougher, parchmentlike lining. Frequently, when the caterpillars are abundant and there is desirable shelter near the nest, several cocoons are formed en masse.

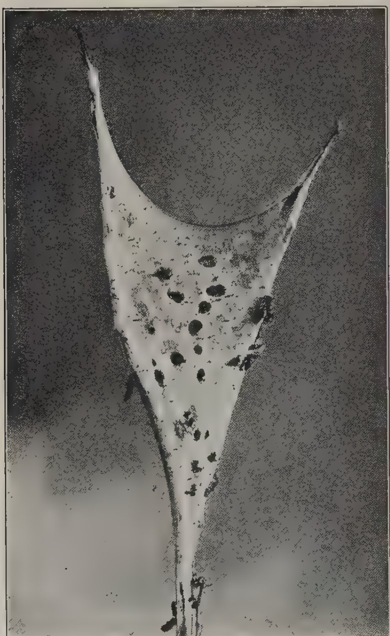

FIG. 77. Web of tent caterpillars which has been riddled by birds. (Reduced)

(Photograph by Weed)

Exhausted by its labors, the caterpillar now becomes quiet, the body shortens to about an inch long, and, finally, the skin splits down the back, is sloughed off into one end of the cocoon, and the transformation to a brown, oval object, the *pupa*, is accomplished. The pupa is about an inch long, and the surface markings of the solid shell outline the legs and wings of the adult moth, but otherwise there is no indication of any relationship to the larva or to the adult, and, had we not seen it emerge from the larval skin, it would be difficult to believe that it is the same animal.

Moth. In about three weeks the pupal shell splits open and the adult moth works its way out of one end of the cocoon. Like all moths

the adults are night flyers and are frequently attracted to lights. They are stout-bodied, of a reddish-brown color, with two nearly

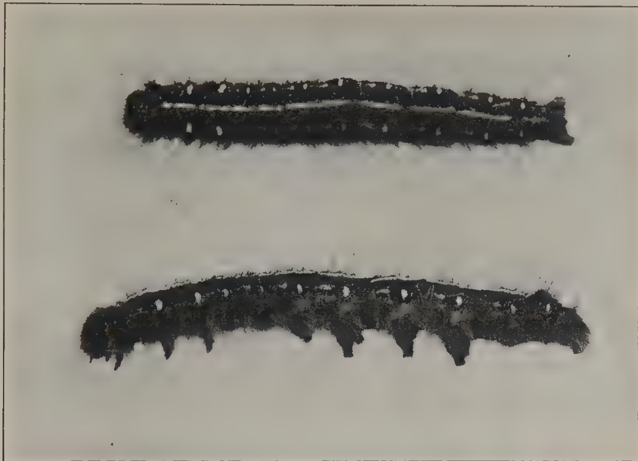

FIG. 78. Tent caterpillar from above and from side. (Slightly enlarged)

parallel white bands extending obliquely across the fore-wings. The males are much smaller and may be distinguished by the more

FIG. 79. Cocoons of the tent caterpillar. (Natural size)
(After Lowe)

feathery antennæ. The sexes soon mate and the females deposit the eggs, which remain on the twigs over winter, as already described.

FIG. 80. Female tent caterpillar moth at rest on leaf. (Slightly enlarged)
(After Lowe)

FIG. 81. Mourning cloak butterfly depositing eggs
(After Weed)

The life of the spiny elm caterpillar (*Euvanessa antiopa*). Complete metamorphosis. What boy does not remember, when the first warm days of spring lured him to a tramp in the woods, that a large, dark purple, yellow-bordered butterfly, usually found sipping the sap from a newly cut tree stump, was the first to greet him? It is one of our commonest butterflies, and we have translated its German name of *Trauermantel* to "mourning cloak butterfly," though it is also often known as the Antiopa butterfly, from its specific name. It is a most cosmopolitan insect, occurring throughout North America as far south as Mexico and Florida, and is found over northern Europe and in Asia.

FIG. 82. Eggs of the spiny elm caterpillar, or mourning cloak butterfly, on willow twig

(Photograph by Weed)

Egg laying. Unlike most butterflies it hibernates over winter, which accounts for its early and often somewhat battered appearance in spring.[1] When the leaves of the elm and poplar are nearly expanded, the female may be found laying her eggs upon the twigs of elm, poplar, and willow. Standing with wings spread, she deposits the eggs in clusters around the twig, as shown in Fig. 81, *a*. In about two weeks the small, blackish caterpillars emerge through round holes eaten out of the upper surface of the eggs, and crawl to the nearest leaf, where they range themselves side by side, with their heads toward the margin of the leaf. Feeding in this position, they nibble the green surface of the leaf but leave the network of veins untouched.

Larva, or caterpillar. They continue to feed side by side for about a week, marching in processions from leaf to leaf as the food supply is exhausted. Each little caterpillar spins a silken thread

[1] We are indebted, for much of the life history, to the account given by Dr. C. M. Weed in *Bulletin 67*, New Hampshire Agricultural Experiment Station.

FIG. 83. The spiny elm caterpillar, or mourning cloak butterfly. (Slightly reduced)
Partly grown caterpillars, chrysalis, empty chrysalis, and adults. (After Britton)

wherever it goes, so that the many threads soon make a fine silken carpet, which serves as a foothold. At the end of a week they molt; the skin of each caterpillar splits down the back, and it crawls out with a new and larger skin, which has been forming beneath the old one. The caterpillars remain quiet during molting, but they soon become active again and feed with increased voracity. Every week for the next three weeks this molting process is repeated, the cast skins decorating the defoliated twigs, as shown in Fig. 84. As they grow, the caterpillars scatter over the neighboring leaves, but still remain in colonies. Their appetites seem to increase as they grow, and

FIG. 84. Twigs denuded by spiny elm caterpillars, bearing their cast skins. (Reduced)

(Photograph by Weed)

they eat more of the leaf substance, devouring all but the midrib and veins when half grown, and, when larger, leave only the midrib. The carpet-like web which they spin also becomes more evident as they grow older, often binding together the ends of near-by twigs, especially where the caterpillars rest after feeding. The full-grown caterpillar is about two inches long, with numerous branched black spines. It is blackish in color, with a row of red spots down the back, and with transverse rows of minute white spots.

Pupa, or chrysalis. The caterpillars are full grown in about four weeks. Dr. Weed, in his interesting account of this species, describes its transformation as follows:

They then leave the tree or shrub on which they have been feeding, and scatter about, seeking some sheltered situation. Having found this, — perhaps beneath a stump or along the underside of a fence, — each caterpillar spins a web of silk along the surface. It then entangles the hooked claws of its hind legs (anal prolegs) in this silken web and lets its body hang vertically with the head end curved upward. It remains in this position for some hours before the skin along the back just behind the head splits apart, and is gradually wriggled upward until it is finally all removed, and there hangs in place of the caterpillar a peculiar object having no definite form — that of the *chrysalis*.[1]

FIG. 85. Mourning cloak butterfly emerging from chrysalis

(Photograph by Weed)

In this quiet chrysalis the insect is apparently almost as inert as a mummy. If you touch it, it

[1] See Fig. 83.

will wriggle a little, but otherwise it hangs there mute and helpless. On the inside, however, the tissues are being made over in such a wonderful way that in about two weeks, from the mummy case into which the caterpillar entered, there comes a beautiful butterfly. When it first breaks the mummy shell its wings are very small, although its body, "feelers," and legs are well developed. By means of the latter it clings to the empty chrysalis while the wings expand. A butterfly in this position, with its wings nearly expanded, is shown in Fig. 86, from a photograph taken from a living specimen. In the course of half an hour the wings become fully developed, and the butterfly is likely to crawl to some firmer support, where it will rest an hour or so before venturing on its first flight.

Fig. 86. Newly emerged mourning cloak butterfly hanging to empty chrysalis while its wings expand and harden

(Photograph by Weed)

In New Hampshire there seems to be but a single generation a year, the newly emerged butterflies appearing in July or August and disappearing during August and September, though they are seen occasionally on warm days in late fall. Under the side of a log, beneath the loose bark of a dead tree, in woodpiles, and in similar situations the butterflies are to be found during the winter lying flat on the side, suspended under a culvert, or in a hollow tree. Apparently they are dead, but if taken into a warm room, they will quickly revive and fly about, and if given a little sugar-water for food, will live for some time. Often in summer they will drop on one side, motionless, evidently feigning death, and if lying on a background of dead leaves, are very difficult to see.

PART II. THE CLASSES OF INSECTS

CHAPTER VI

THE CLASSIFICATION OF INSECTS

Identity of insects. If a crop of potatoes is being destroyed by the Colorado potato beetle, it is at once recognized as the cause of the injury, and the method of control is known or may be ascertained from books or bulletins. In many cases, however, insects are found abundant upon a crop which is evidently being injured, but the casual observer may not be able to determine just which are responsible for the injury without devoting more time to the matter than is available, or without more knowledge of the habits of insects than he possesses. Thus, when a colony of plant-lice is found ruining a crop, there are usually found with them various insects which are either preying upon them, as do the ladybird beetles, aphis-lions, and syrphus-fly larvæ, or caring for them, as do the ants. No one would consider the ants as producing the aphides, but it is not at all uncommon for those unacquainted with the life history of plant-lice to assert that they are produced by the ladybird beetles or other insects which are found associated with them, which are consequently destroyed when they should be protected. If the insect is very evidently the cause of the injury, but of unknown identity, it is of the utmost importance to identify it, so that its habits and the best means of control may be ascertained. A knowledge of the different kinds of insects is thus seen to be not only a matter of theoretical or biological knowledge, but of considerable practical importance.

The classification of insects and the manner in which they may be identified may be illustrated by a study of the ladybird beetles already mentioned. Upon examining a ladybird beetle, we at once recognize it as a beetle from the hard wing-covers, with the membranous hind-wings folded beneath them, and the biting mouth-parts.

Thus we ascertain that it belongs to one of the several divisions, called *orders*, into which all insects are divided. known as the order *Coleoptera*. Some nineteen orders of insects are now recognized by entomologists, but only six or seven are of any economic importance. Most of the orders are distinguished by the structure of the wings, and the names of the orders usually end in the syllable *ptera*, from *pteron*, meaning "a wing." A brief survey of the beetles shows that the order *Coleoptera* consists of numerous *families*, which are grouped together according to the number of segments in the hind tarsi. An examination of the hind tarsus of a ladybird beetle reveals that it is composed of but three segments, which is characteristic of only one family, the *Coccinellidae*, the family of the ladybird beetles. A brief account of this family indicates that nearly all of its members are predacious upon plant-lice or other small insects, and that the more common forms are small yellow or red beetles with black spots, like the specimen in hand. It is evident, therefore, that our ladybird beetle is feeding upon the plant-lice and is in no way responsible for them, for a similar study of the plant-lice would show that they belong to an entirely different order (the Hemiptera), which has sucking mouth-parts and an entirely different life history. We should also learn from the account of the Coccinellidae that the little long-legged, blackish, brilliantly marked larvæ which accompany the ladybirds are the young stage from which they develop, and that these larvæ also feed upon the plant-lice. Probably we should find several different kinds of beetles, evidently all of the ladybird family, but differing in size, shape, and coloration. Should we desire to speak exactly of any one sort, we should be obliged to determine to what *genus* of the family it belonged, and then to which of several species in that genus. Usually the amateur will not be able to identify an insect farther than to its family, but in the case of common forms, especially those commonly injurious, the illustrations or descriptions of the insect or its characteristic work as given in textbooks, or the comparison of the specimen with those of a named collection, if one is available, will make it possible to definitely determine the species.

Scientific names. The name of the *genus* and *species* together is commonly called the *scientific name*, and is in Latin and usually

printed in *italics* for its easy recognition. Scientific names are a necessity, because the common name of an insect in one community may often be applied to an entirely different species in some other section, or different common names may be applied to the same insect; and they are written in Latin because that is understood by scientists in all countries, and is common to them all, which is true of no other language. The ladybird beetle in question may have been of the species *novemnotata*, meaning nine-spotted, and of the genus *Coccinella*, which is the typical genus of the family. This name is written *Coccinella novemnotata* Herbst. The name of the genus is always placed first and commenced with a capital letter, the name of the species following and commencing with a small letter. Botanists often commence the specific name with a capital letter if it is named for some person or country, but zoölogists commence all specific names with small letters to distinguish them readily from the generic names. After the scientific name proper is often placed the name, or an abbreviation of the name, of the author who originally described the species (as Herbst, in the above), for not infrequently different authors will use the same name for different species, which often results in endless confusion when the name of the author who has described each species under the name is not given. Thus the generic and specific names of a plant or animal are analogous to the Christian name and surname of a man, except that in the case of the latter the name applies to an individual, while in the former it applies to a large number of individuals. The scientific name also has a somewhat analogous significance and use. Thus, if we speak of Patrick O'Connor or Napoleon Bonaparte, we at once think of the individuals known to us by those names. But the name also tells us that Patrick is of the O'Connor family, with their general characteristics, and we know the O'Connors to be from the Emerald Isle, which we know to be inhabited by people of the Caucasian race, and, similarly, we know the Bonapartes to be Corsican. In the same way the specific name of a plant or animal signifies its relationship to those acquainted with the different sorts. Thus the specific name *novemnotata* (or *9-notata*) at once signifies that this particular species of beetle has nine spots and is a separate species from *bipunctata*, which has but two spots, while the generic name indicates

that it belongs to the genus *Coccinella*, to which this species and many others belong, and which we recognize in this case as probably belonging to the family *Coccinellidae*, which we know to be a family of predacious beetles of the order *Coleoptera*.

Thus animals and plants are divided into the following successive groups:

GROUP EXAMPLES

Phylum (*Arthropoda*)
Class (*Insecta*)
Order (*Coleoptera*)
Family (*Coccinellidae*)
Genus (*Coccinella*)
Species (*novemnotata*)

Coccinella novemnotata Herbst.

Species. The exact definition of a species has worried naturalists since the time of Linnæus and is still under dispute, so that no exact definition will be attempted. It is evident that, inasmuch as it applies to a large number of individuals, and as we know that individuals vary exceedingly, it is largely a conception for our convenience in designating forms of life. Inasmuch as we now believe that all forms of life have had a common origin and have been gradually evolved from one or at least a very few original ancestors of all life during the millions of years of the earth's history, and as we know that species of plants and animals are now being formed, while others have disappeared from the earth, it is evident that the species now being formed will be very similar to each other and will be separated with great difficulty, if at all; whereas those species which have existed for a long period of time, and whose nearly related species have disappeared, will be easily recognizable and form very distinct species. In short, it may be said that *a species is an aggregation of individuals of so similar a structure that they might all have been derived from the same parent, which are more similar to each other than to any other individuals, and which, when bred together, produce progeny of the same degree of likeness, which will also be fertile and produce their kind*. The number of individuals in a species and their distribution

over the earth depend upon its habits and food supply. Some species are exceedingly limited in their distribution, — as, for instance, the little butterfly *Oeneis semidea*, which inhabits only the highest peaks of the White Mountains, — while others are quite cosmopolitan, living in many distant parts of the world and with quite different food habits, an example being the bollworm (*Heliothis obsoleta*), which is found on every continent. Some species are so rare that but one or two specimens have ever been taken, while others occur in such countless myriads as to become the worst pests of crops.

Genus. As a species is composed of individuals of similar structure, so a *genus* is formed of a number of species having some common characteristics which make them more nearly related to each other than to any other species. In the same way genera are grouped together into *families*, which have some common characteristics distinguishing them from other families of genera, and families are likewise grouped into *orders*. Frequently, various other subdivisions are made for the purpose of bringing out certain relationships, which are evident but which do not seem to warrant definite rank. It should be observed that no standard exists as to what structural characters are sufficient for establishing a species, genus, or family, and that structures which will separate species in one order are of sufficient importance to separate families in another order, this all depending upon the constancy and relative importance of the character. Thus, orders are commonly divided into suborders, families into subfamilies, and genera into subgenera, while we recognize varieties and races of individuals within a species, as, for instance, the varieties and races of garden plants and domestic animals. In each case the subgroup is composed of a portion of the larger group, which has some common characters distinguishing it from the other subgroups of the same rank. Such terms as *sections*, *divisions*, *tribes*, and *series* are also used in the same sense.

Inasmuch as some three hundred thousand species of insects have been described, it would evidently be impossible for any one person, or any one library, to have all the descriptions which are scattered throughout the scientific books and journals of all countries and languages. Hence most entomologists acquire a general knowledge of the larger groups and then make a special study of some one

family or small portion of a family, sending the insects of other groups to specialists of those groups for determination, and thus building up collections which they may use for the subsequent determination of specimens by comparison. The common families, and particularly those of economic importance, may usually be recognized by the amateur, and the identification of the family will usually indicate the possible economic importance of a given insect, and may lead to its definite identification, if it is a common form.

In the following pages we have endeavored to give a very brief account of the characteristics of the more common orders and families of insects. Keys for their determination will be found in Chapter XX.

CHAPTER VII

BRISTLETAILS AND SPRINGTAILS (*APTERA*)

Characteristics. Wingless insects which have no metamorphosis. Mandibles and maxillæ retracted within the head, but used for biting and chewing soft substances. True compound eyes rarely present; a group of simple eyes on each side of head in some genera. Abdomen sometimes furnished with rudimentary jointed appendages.

This is a relatively unimportant order from the economic standpoint, but is of interest from the fact that it includes the most

FIG. 87. Silver fish-moth (*Lepisma saccharina*). (Enlarged)

A household nuisance and a good example of the bristletails. (After Marlatt, United States Department of Agriculture)

primitive insects now in existence. The name *Aptera* is given on account of the entire absence of wings, in consequence of which

there is no metamorphosis. In some forms there are rudimentary appendages on the underside of the abdomen, which are supposed to be degenerated abdominal legs, though not now capable of being used as such. The order is divided into two distinct suborders, sometimes considered separate orders.

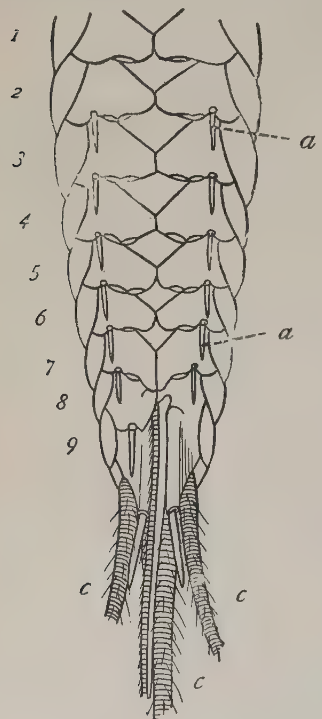

FIG. 88. Underside of abdomen of a female *Machilis maritima*, to show rudimentary limbs (*a*) of segments 2 to 9; *c*, cerci. (Enlarged)

(After Oudemans, from Folsom)

Bristletails (*Thysanura*). One of the commonest bristletails is the little shiny fish-moth, which annoys housekeepers by getting into starched clothes, among books, papers, etc. It is about half an inch long, with long antennæ and three bristles extending half the length of the body from the tip of the abdomen, and is covered with silvery scales which glisten as it darts around in a bookcase or drawer, reminding one of a fish's scales flashing in the sunlight. They are very soft-bodied little insects, more abundant in warm climates, and feed on starchy matter or soft paper. In some species of bristletails the bristles have been modified into forceplike appendages. Most bristletails are much smaller than the fishmoth, and are found beneath stones, logs, and loose bark, and in similar situations; and one genus (*Machilis*), found in many parts of the world, has rudimentary abdominal appendages, as shown in Fig. 88.

FIG. 89. The pond-surface springtail (*Smynthurus aquaticus*) with spring extended. (Much enlarged)

(After Schött, from Kellogg)

Springtails (*Collembola*). Every boy who has worked in a northern maple-sugar "bush" knows the little snow fleas, large numbers of which jump around on the snow and have a propensity for getting into the sap buckets. Other species are found on

the surface of stagnant pools, in manure piles, in the decaying hollows of trees, in gardens, hotbeds, window boxes, and, in general, in moist places where decaying vegetation is found. They are usually microscopic in size, from one tenth to one twentieth of an inch long, but have an exceedingly interesting structure. Projecting forward from the underside of the next to the last abdominal segment is a long abdominal appendage, or spring, by the extension of which the insect is enabled to shoot forward as if shot from a catapult, jumping a considerable distance. As the springtails feed only on decaying vegetation, they are never injurious, unless exceptional numbers render them a nuisance. Occasionally such immense numbers of small springtails are found in manure heaps or on the surface of stagnant pools or ponds as to attract attention to them.

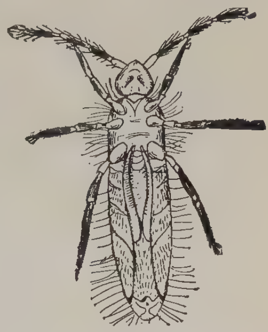

FIG. 90. Underside of the American springtail (*Lepidocyrtus americanus*) with the spring folded underneath the body. (Much enlarged)

(After Howard and Marlatt)

Many of these little springtails are prettily colored with patterns composed of very minute scales. For this reason they are often used as test objects for microscopes, the quality of the lens being determined by its efficiency in revealing the very fine markings on these tiny scales.

CHAPTER VIII

COCKROACHES, GRASSHOPPERS, KATYDIDS, AND CRICKETS (*ORTHOPTERA*)

Characteristics. Insects with four wings: the first pair, more or less leathery, not used for flight, and forming wing-covers for the hind-wings; the second pair membranous, larger, with numerous veins, and folded like a fan. Mouth-parts formed for biting. Metamorphosis, incomplete.

The members of this order are among the best known of any of our common insects, possibly because many of them form the

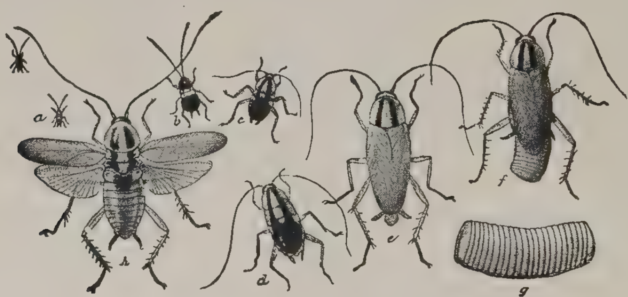

FIG. 91. The German roach (*Ectobia germanica*)

a, first stage; *b*, second stage; *c*, third stage; *d*, fourth stage; *e*, adult; *f*, adult female with egg-case; *g*, egg-case (enlarged); *h*, adult with wings spread. (All natural size except *g*.) (From Riley)

main strength of the insect orchestra of a drowsy summer evening, while others are among the most destructive pests. We have already become fairly well acquainted with a common grasshopper (pp. 53–56) which forms a good type of the order. The biting mouth-parts, leathery fore-wings, and fanlike hind-wings make the order easily distinguishable, and from the latter characteristic comes the name "Orthoptera," from *orthos* (straight) and *pteron* (wing), referring to the straight-folded wings.

The order is divided into six families, which are readily distinguished as regards both structure and habits.

Cockroaches, or running Orthoptera (*Blattidae*). The Croton bug, or German cockroach, is a familiar pest in all eastern cities, wherever kitchens, pantries, and living rooms are not kept scrupulously clean. The name "Croton bug," as well as that of "water bug," comes from the fact that it was introduced into New York City about the same time as the Croton water system, with which it was associated in the popular mind. Roaches not only make themselves a nuisance by getting into everything, but

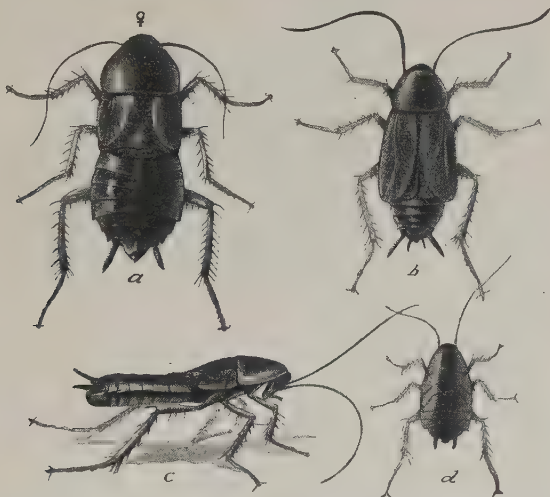

FIG. 92. The oriental roach (*Periplaneta orientalis*). (Natural size)

a, female; *b*, male; *c*, side view of female; *d*, half-grown nymph. (After Marlatt, United States Department of Agriculture)

often do serious damage by gnawing the bindings of books, eating off wall paper, etc. Our common native species are larger, almost black, and live under stones and logs; they are of no economic importance.

The body of a roach is flattened, due to its habit of living in narrow cracks and similar out-of-the-way places, and the legs are long and enable it to run with remarkable swiftness for so awkward-looking an insect. About two dozen eggs are laid together in a single pod-shaped mass, which is covered with a brown cement, making it look much like a large bean, and is left lying in a crack or quite exposed.

The mantids, or grasping Orthoptera (*Mantidae*). Mantids are found commonly throughout the southern states, and form the only

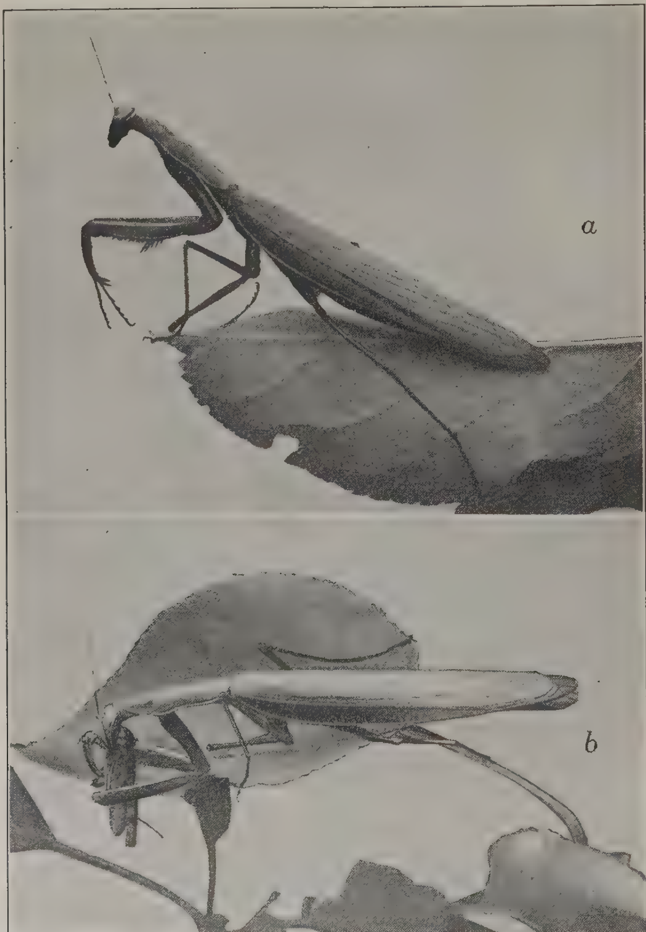

FIG. 93. The common European praying mantis (*Mantis religiosa*). (Natural size, from life)

a, adult mantid patiently waiting or "praying" for its prey; *b*, busily engaged in eating a live grasshopper. (After Slingerland)

family of Orthoptera which is strictly predacious, as they feed entirely on other insects, and are therefore beneficial. They are curious-looking insects and are called praying mantes, from the prayerlike

attitude assumed by the forelegs, which really, however, are merely held ready to quickly grasp any unwary insect prey which may come within reach.

FIG. 94. Egg mass of the praying mantis. (Natural size)

(After Slingerland)

Early writers on natural history had many curious fancies concerning this insect, which are evinced by the name of our most common species, *Mantis religiosa* (*mantis*, "a prophet"), the name undoubtedly referring to the pious attitude.

FIG. 95. Walking-stick resting on birch twig, the leaves of which were attacked by the birch-leaf skeletonizer

(After Weed)

There are many local names for them, such as rear-horses, devil-horses, etc., while the southern negroes know them as mule killers and other similar names, from the superstition that the brown saliva from their mouths will kill a mule. The eggs are laid in shingled masses, attached to a twig or weed, and are coated with a hard, gummy covering. The young, as well as the adults, feed on insects and are extremely difficult to rear, as they are rabid cannibals, eating

FIG. 96. A pair of walking-sticks on a birch twig (Photograph by Weed)

each other with avidity. The adults have an extremely long prothorax, with a small transverse head, and long legs. In many tropical forms the wings are bright green and closely resemble leaves, thoroughly protecting the insect as it awaits its prey.

Walking-sticks, or walking Orthoptera (*Phasmidae*). The walking-sticks are aptly described by their name; so closely do they resemble the twig of a bush or tree that they are found with difficulty and usually quite by accident. Only one species occurs in the northern states, which feeds upon the foliage of forest trees and is particularly common on hazel and beech, the body color varying from greenish to brown according to the surroundings. In the tropics are many phasmids of large size and having wings which closely resemble leaves in both color and shape. The large, oval eggs are dropped loose upon the ground, where they pass the winter and hatch the next summer.

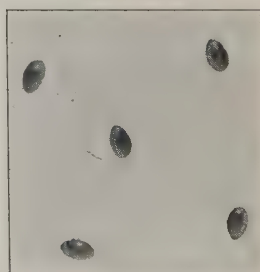

FIG. 97. Eggs of the walking-stick

The next three families all have the hind legs adapted for jumping, and are commonly grouped together as the jumping Orthoptera. Most of the forms in these three families also have the ability to produce sounds either by their legs or wings.

The short-horned grasshoppers, or locusts (*Acrididae*). The word "grasshopper" is an American term for the insects which in the Old World are called *locusts*, as they are termed in the Biblical account of the Egyptian plague of locusts. The locusts include all of our more common grasshoppers, which have the antennæ shorter than the body, and a short ovipositor. Many of them are seriously injurious. Their structure and life habits have already been sufficiently discussed (Chaps. V, XVI), so that we shall merely consider a few of the more common and important forms. The most common throughout the East is the small red-legged locust (*Melanoplus femur-rubrum*) and the nearly related lesser migratory locust (*Melanoplus atlantis*), hardly distinguishable from each other by the casual observer, both of which are abundant in our pastures, and often do serious injury to grass and garden crops. One of the most common forms east of

FIG. 98. The red-legged locust. (Natural size)

(After Riley)

FIG. 99. Two-striped grasshopper (*Melanoplus bivittatus*). (Natural size)

(After Riley)

FIG. 100. The bird grasshopper, or American locust. (Natural size)

(After Riley)

the Rockies is the Carolina locust, which flies up along the roadside and in waste places where it lives. It closely matches its surroundings

in color, but the hind-wings are black, with a broad yellow edge quite conspicuous in flight. Throughout the Mississippi Valley the differential locust (*Melanoplus differentialis*) is one of the most destructive forms, being particularly injurious after floods, when it multiplies rapidly on the uncultivated land which has been flooded. A generation ago (1874–1877), the crops of the western part of the Mississippi Valley were utterly destroyed for several years by the clouds of Rocky Mountain or migratory locusts (*Melanoplus spretus*) which swooped down from the tablelands of the northwest, where they bred and multiplied. Accounts of the numbers and voracity of these locusts seem almost incredible to-day, except to those who have seen an occasional outbreak in the northwest, for with the settling and development of the western plateau they have become less abundant, and the species is now injurious only very rarely in Manitoba. In the middle and southern states the large bird grasshopper, or

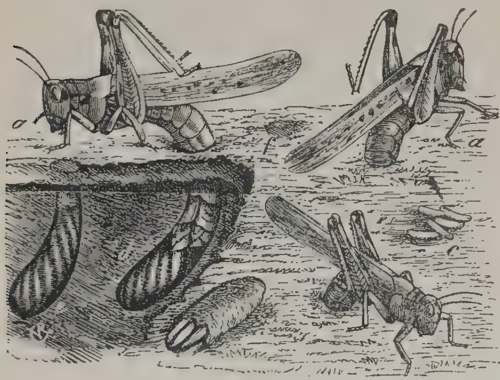

FIG. 101. Rocky Mountain locust laying eggs

a, females ovipositing, with earth cut away to show tip of abdomen placing eggs at *d*, and completed egg mass at *e*; *c*, eggs. (After Riley)

FIG. 102. The Carolina locust (*Dissosteira carolina*), female. (Slightly enlarged)

(After Lugger)

American Acridium (*Schistocerca americana*), is common, but rarely becomes numerous enough to be seriously injurious. It is one of our largest species (nearly three inches long) and makes as much commotion as a small bird as it flies up before one. In the Gulf States, and on the plains of the southwest, occur our two largest species, known as the lubber grasshopper and the clumsy locust, so called from their clumsy movements. Both are short-winged and unable to fly, but manage to travel considerable distances.

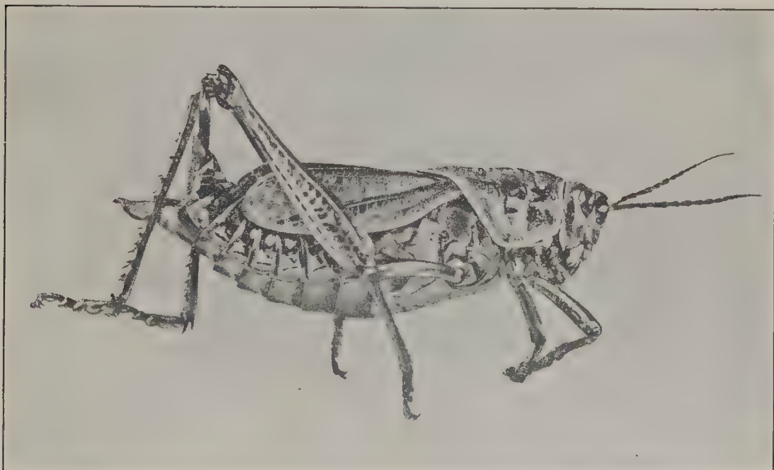

FIG. 103. The southern lubber grasshopper (*Dictyophora reticulata*). (About natural size)

The long-horned grasshoppers (*Locustidae*). The katydids and meadow grasshoppers form another family readily distinguished by their slender antennæ, which are much longer than the body and give the group the name "long-horned," in contrast to the short antennæ of the grasshoppers, or locusts. The ovipositor of the female is also long and sword-shaped. Unfortunately, the scientific name of this family, *Locustidae*, has the same root as the true *locusts*, or grasshoppers, with which they should not be confused on that account. The base of the wings of those males which have well-developed wings is usually constructed for sound producing, so that when the wings are rubbed together and set vibrating, the characteristic note is made. The Japanese inclose

FIG. 104. A common katydid. (Natural size)
(Photograph by Weed)

some of the best of these insect songsters in small cages, in much the same manner as we do song birds. The "ears," or auditory organs, of the long-horned grasshoppers, instead of being in the first abdominal segment, as in the locusts, are situated on the tibia of the forelegs.

The light green or reddish-brown meadow grasshoppers are common occupants of our meadows, where they may be heard calling to each other at dusk. The antennæ are usually very long, and often the ovipositor is as long as the body, being adapted for placing the eggs in the stems and roots of grasses, where they are usually laid.

The katydids are larger, of a bright green color, and with much broader wings, which are frequently quite leaflike in both shape and color. The katydids feed mostly in trees, though some prefer

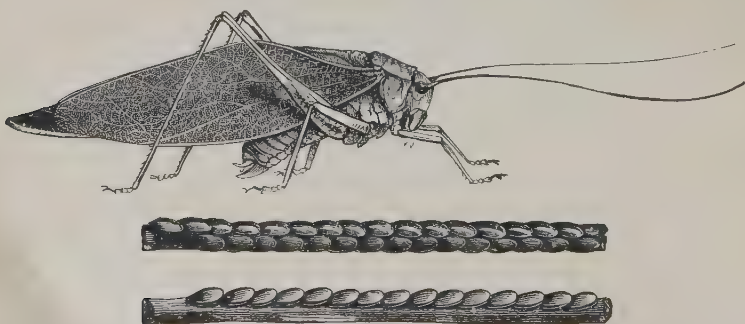

FIG. 105. A katydid (*Microcentrum laurifolium*) and its eggs. (Natural size)
(After Riley)

bushes and shrubs. The eggs are laid along the edge of a leaf or along a stem, slightly shingled, as shown in Fig. 105, being quite different from those of any similar insects and thus easily recognizable.

FIG. 106. The western cricket (*Anabrus simplex*), adult female. (Natural size)

(After Gillette)

In this family there are two groups of wingless forms: the cricketlike grasshoppers, which are to be found under stones and rubbish, particularly in woodlands, and the shield-backed grasshoppers, which look very much like crickets. One of them, known as the western cricket (*Anabrus*), which is about one and one half inches long, often becomes so abundant in the northwestern states as to be very destructive to crops.

FIG. 107. The black cricket, male and female

(After J. B. Smith)

The crickets (*Gryllidae*). The common black or brownish crickets, with their familiar chirp, are well known to every one. The wings are laid flat on the back when at rest, instead of meeting like a roof as in the grasshoppers, the antennæ are long, and the ovipositor is long, but cylindrical in section, being lance-shaped rather than sword-shaped as in the grasshoppers. Our common crickets usually feed upon vegetation, and very rarely become injurious, though some are predacious and at times are uncompromising

cannibals. The eggs are laid in the ground in the fall and hatch the next summer. The males have the best-developed musical apparatus of all the orthopteran orchestra. The principal vein, which extends along the base of the wing-cover, is ridged like a file, and on the inner margin of the wing-cover, a short distance from the base, the edge is hardened so that it may be used as a scraper, or rasp. Elevating his wings to an angle of forty-five degrees, and arranging them so that the scraper of one rests on the file of the other, he moves them to set the neighboring wing membranes into vibration, thus producing the shrill call or the faint chirp, according to his mood.

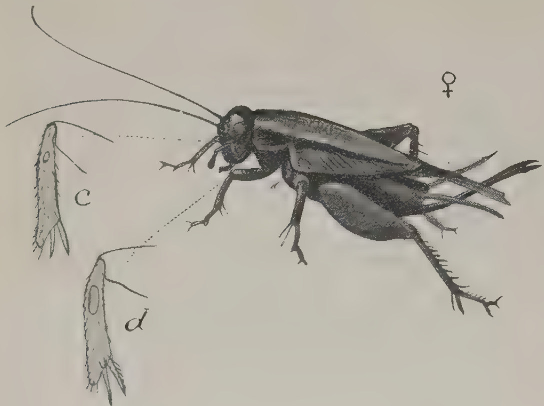

FIG. 108. Female of *Gryllus assimilis*, with inner and outer views of auditory membranes on front tibiæ, at *c* and *d*
(After Marlatt, United States Department of Agriculture)

The tree crickets are quite different from the common black sorts and are arboreal, as their name indicates. They are of a creamy-white or light yellowish color, often slightly tinged with green, and the wings are transparent. The antennæ are much longer than the body, which is about half an inch long, and the ovipositor is well developed. The wings when at rest are usually held so as to form a long

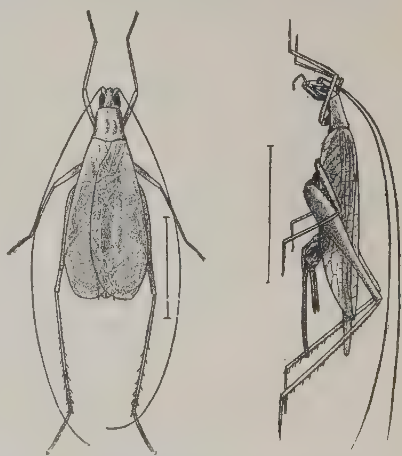

FIG. 109. A tree cricket (*Œcanthus fasciatus*), male and female
(After Lugger)

wedge tapering toward the head. The young tree crickets are somewhat beneficial, as they feed upon plant-lice, but the adults do considerably more injury by slitting the twigs of cane fruits, fruit trees, cotton, etc., in which their eggs are deposited, and beyond which the twigs usually die.

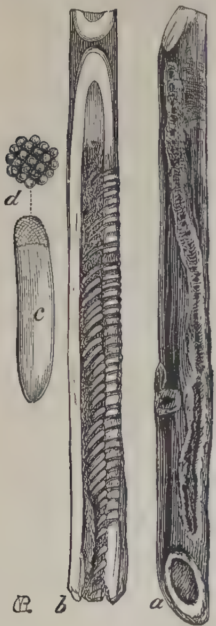

FIG. 110. Eggs of a tree cricket (*Œcanthus nigricornis*)

a, blackberry cane, showing egg punctures; *b*, the same split, to show the arrangement of the eggs; *c*, egg very much enlarged; *d*, its tip still more enlarged. (After Riley)

One small group of crickets, called mole crickets, are usually found in the ground, burrowing here and there by means of the front tibiæ, which form shovels admirable for that purpose. Mole crickets are more abundant in the South and Southwest, where they feed upon the roots of plants, but are very rarely injurious. In Porto Rico, however, the *changa* is the most serious insect pest of the island, annually doing one hundred thousand dollars' worth of damage to the staple crops.

FIG. 111. Changa (*Scapteriscus didactylus* Latr.)

A mole cricket which is the most serious insect pest in Porto Rico. (After Barrett)

Earwigs (*Euplexoptera*). The earwigs are nearly related to the Orthoptera, though they are often placed in a separate order, Euplexoptera, which means "well-folded wing," referring to the wing, which is folded lengthwise, like that of the grasshopper, and then crosswise. They are small insects, our common species

being from one fourth to one half an inch long. The wing-covers are short and thick like those of some beetles, and at the tip of the abdomen is a pair of strong, forceplike appendages. Earwigs

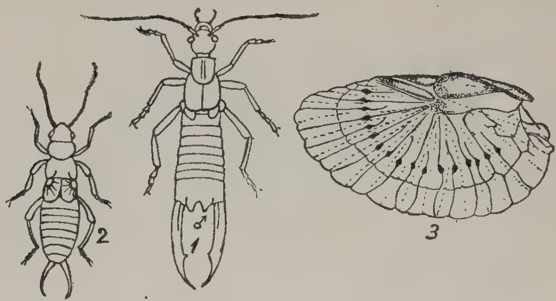

FIG. 112. An earwig (*Forficula taeniata*). (Enlarged)

1, male; 2, female; 3, wing showing fanlike folds and joints where the tip is folded on the base

are rare in the United States, except in the South, and are not injurious. The common name "earwig" arises from an old superstition that they crawl into the ears of sleepers and kill them. In the South they often fly into lights, and in Europe and subtropical countries they sometimes become injurious.

CHAPTER IX

THE NERVE-WINGED INSECTS, SCORPION-FLIES, CADDIS-FLIES, MAY-FLIES, STONE-FLIES, AND DRAGON-FLIES

The earlier naturalists grouped all of the insects having four membranous wings with numerous fine cross veins, or nervures, as they were then called, into the order Neuroptera, or nerve-winged insects, from *neuron* (nerve) and *pteron* (wing). Further study has

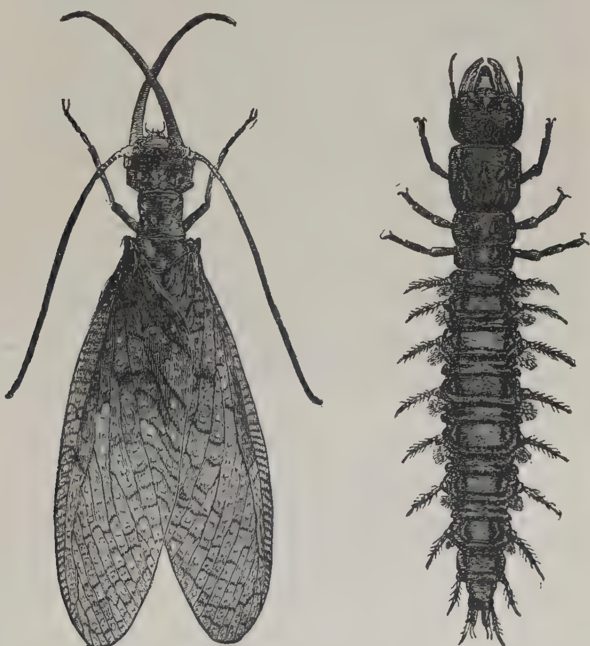

FIG. 113. The adult male dobson-fly and its larva, the hellgramite
(After Comstock)

shown that these insects are not so nearly related, and that they should be divided into several distinct orders, to exhibit their true relationship. Few of them have any economic importance, and

they may conveniently be considered together and termed "neuropteroid insects."

True Neuroptera. In the true *Neuroptera* the wings are usually of equal size, with numerous cross veins, the mandibles are well developed, and the metamorphosis is complete. The larvæ are carnivorous, and the mandibles are usually long and pointed. One of the best-known forms is the large hellgramite (*Corydalus cornuta*), whose larvæ, known as *dobsons*, are the favorite bait of the bass fisherman. The larvæ live under stones in swift-flowing

FIG. 114. Cluster of eggs of the lace-winged fly (*Chrysopa*). (Greatly enlarged) (After S. J. Hunter)

streams, where they feed on the young of various aquatic insects. They are readily recognized by the leglike appendages and a large tuft of tracheal gills on either side of each abdominal segment (Fig. 113). It requires nearly three years for the larva to become full grown, when it forms a cell beneath a stone, or some object near the bank, and pupates, the adult appearing about a month later. The adults are readily recognized, as they have a wing expanse of from four to five and one half inches and the males have remarkably long mandibles. On the rocks under which the larvæ live the eggs are laid in chalklike masses of from two to three thousand.

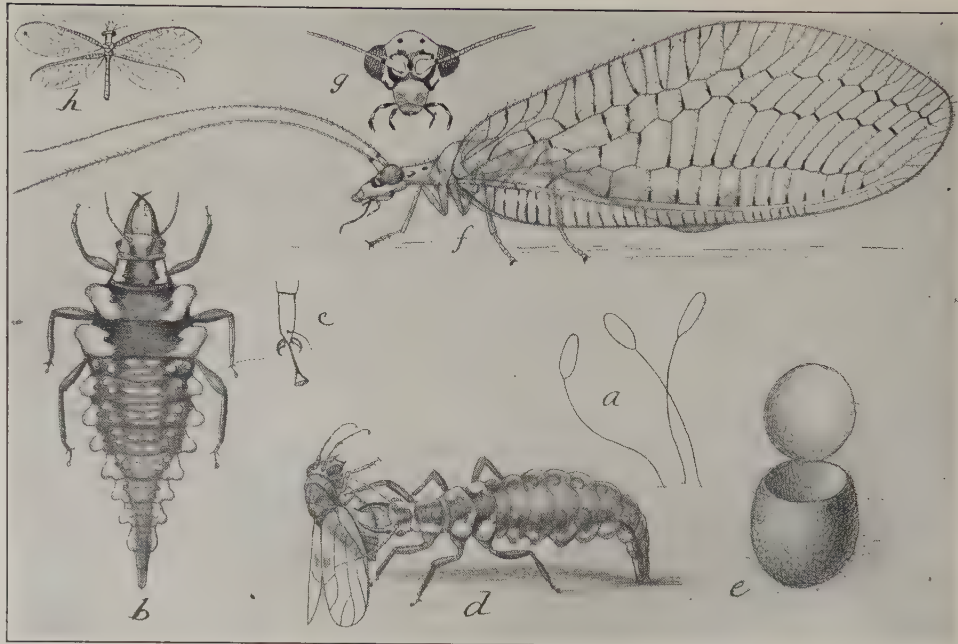

FIG. 115. The lace-winged fly

a, eggs; *b*, full-grown larva; *c*, foot of same; *d*, same, devouring a pear psylla; *e*, cocoon; *f*, adult insect; *g*, head of same; *h*, adult (natural size). (All enlarged except *h*.) (After Marlatt, United States Department of Agriculture)

The aphis-lions (*Chrysopidae*) are among the most important enemies of the noxious plant-lice. The larvæ are small, dark-colored, spindle-shaped insects, from one fourth to one third of an inch long, with large, pincer-like jaws, much longer than the head, with which they grasp the aphides. On the inside of each mandible is a deep groove, against which the maxilla fits, thus forming a tube through which the juices of the prey are sucked into the mouth. When full grown, the larva spins a small, globular cocoon of pure white silk, in which it pupates. Frequently the old cocoons will be found with a small, circular lid which the adult has opened in making its escape. The adults are about an inch long, of a delicate pale green color, with brown antennæ and finely veined wings, which are held like a roof over the back, and which have given them the name of "lace-winged flies." The eyes are a glistening

FIG. 116. A Myrmeleonid, the adult of the ant-lion

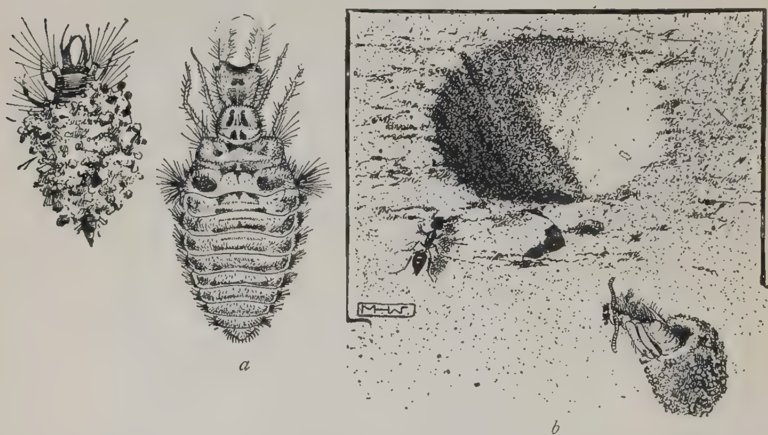

FIG. 117. The ant-lion

a, larva of *Myrmeleon* sp. (three times natural size); *b*, pit of ant-lion, *Myrmeleon* sp., and below a pupal sand-cocoon from which the adult has just issued, the pupal skin remaining (natural size). (After Kellogg)

gold, from which they are sometimes called golden-eyes. The larvæ feed not only upon plant-lice, but upon any soft-bodied insects which they can overpower, or on soft insect eggs, and will not infrequently attack their own species. The adults seem fully aware of these cannibalistic tastes, for they lay the little white eggs on stalks about half an inch high, placing them out of the reach of the larvæ.

FIG. 118. A scorpion-fly (*Panorpa rufescens*). (Twice natural size)

(After Kellogg)

In the undisturbed dust beneath an old shed, or beneath cliffs, or along warm banks, one will frequently find the little funnel-shaped pits of the ant-lions (*Myrmeleonidae*), sometimes locally known as "doodle bugs." At the bottom of the pit may be seen two outstretched jaws awaiting any unwary insect which may slide down the crumbling sides. The larvæ are not unlike those of the aphis-lions in general appearance, but have a larger abdomen and a small thorax and slender legs. The adults are dusky-colored, with long, narrow, delicate wings. They are poor fliers and are often attracted to lights (Fig. 116).

The scorpion-flies (order *Mecoptera*) are readily distinguished by the long head, which is prolonged into a beak, at the end of which are the biting mouth-parts. They receive their common name "scorpion-flies" from the terminal segment of the males of the most common forms, which is enlarged and bears clasping organs, so that it looks like the fang at the tip of the body of a scorpion. They are entirely harmless, however, being carnivorous both as adults and as larvæ. The adults are most commonly found on foliage in shady places, though they not infrequently fly into lights, while the larvæ look much like caterpillars and live in the soil.

FIG. 119. Scorpion-fly larva (*Panorpa* sp.). (Three times natural size)

(After Felt, from Kellogg)

The caddis-flies (order *Trichoptera*)[1] have wings with but few cross veins but more or less densely clothed with hairs, thus being related

[1] From *thrix* (a hair) and *pteron* (a wing).

to both the neuropterous insects and the Lepidoptera. The mouth-parts of the adults are quite rudimentary. The hind-wings are often somewhat larger than the fore-wings and are then folded under them in repose, the fore-wings being held like a roof over the back. The antennæ are usually very long and slender. The larvæ are aquatic and form an important item of fish food. Some of them build most interesting little cases from grains of gravel, small shells, bits of twigs, pine needles, or whatever rubbish may be at hand, lined within with silk, which they carry around with them, the head and thorax projecting out as they move or feed. Every small pool or brook harbors some of these interesting case bearers, which will hardly be distinguished except by closely watching the bottom until they are seen in motion. Most of these larvæ are herbivorous, feeding on whatever vegetable matter is available, and look like small caterpillars. The caddis-worms of one group construct silken nets across small rapids, between stones, or upon the brink of little waterfalls, which are doubtless of service in catching the tiny insects which float downstream, as the larvæ which make them are known to be carnivorous. When ready to change to a pupa, the caddis-worm closes up the entrance to its case, but leaves an opening for the water to flow through so that the pupa can breathe, sometimes making a simple grating of silk over the entrance. Upon transforming to the adult the caddis-fly secures almost immediate use

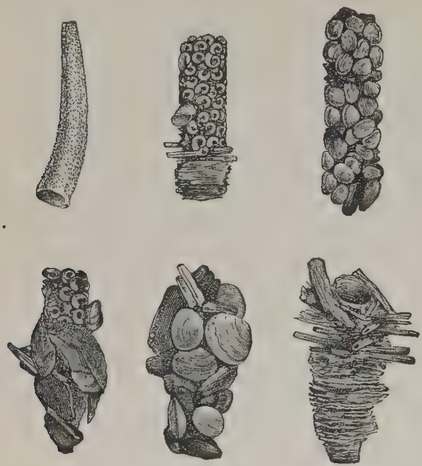

FIG. 120. Caddis-fly larval cases. (Enlarged) (After Furneaux)

FIG. 121. Adult caddis-fly (*Goniotaulius dispectus* Walk). (Enlarged) (After Needham)

of its wings, as is highly necessary if it is not to be drowned. Most insects require several minutes or even hours for the wings to expand and harden, but Professor Comstock observed a caddis-fly which took flight immediately upon emergence from the water. The adults are usually grayish, brownish, or dusky in color, marked with black or white, and are rarely observed except as they fly into lights.

Pseudoneuroptera, with incomplete metamorphosis. All of the three orders just considered have a complete metamorphosis and are more or less closely related. The next three orders are all aquatic and have an incomplete metamorphosis, for which reason they are often grouped together as false Neuroptera (*Pseudoneuroptera*).

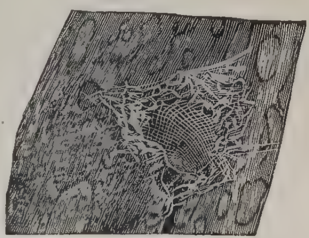

FIG. 122. Net of a net-building caddis-worm

(After Comstock)

The May-flies (*Ephemerida*)[1] are well named, for they are the most ephemeral of insects. The wings are exceedingly delicate and the fore-wings are much the larger, the hind-wings sometimes being entirely wanting. The mouth-parts of the adults are exceedingly rudimentary, and they probably take no food. The antennæ are short, but at the end of the long, soft abdomen are two or three long, many-jointed, threadlike appendages, the cerci, which are quite characteristic of the May-flies. On warm nights of late spring and early summer the lights of towns near rivers and lakes are often darkened by myriads of May-flies. They are light brown or dusky colored, with wings expanding from one to one and one half inches, and with cerci fully as long. The nymphs live at the bottom of ponds, streams, and lakes, feeding on small insects and vegetable matter in the ooze. Along each side of the nymph's abdomen is a row of delicate, platelike, fringed tracheal gills, through which it breathes, and at the tip of the abdomen are three feathery appendages. The legs are strong and enable it both to walk and to swim. The nymphs molt very frequently, there being in some species as many as twenty molts. After about the ninth molt the wing pads commence to appear on the back, and become

[1] From *ephemeros* (lasting but a day).

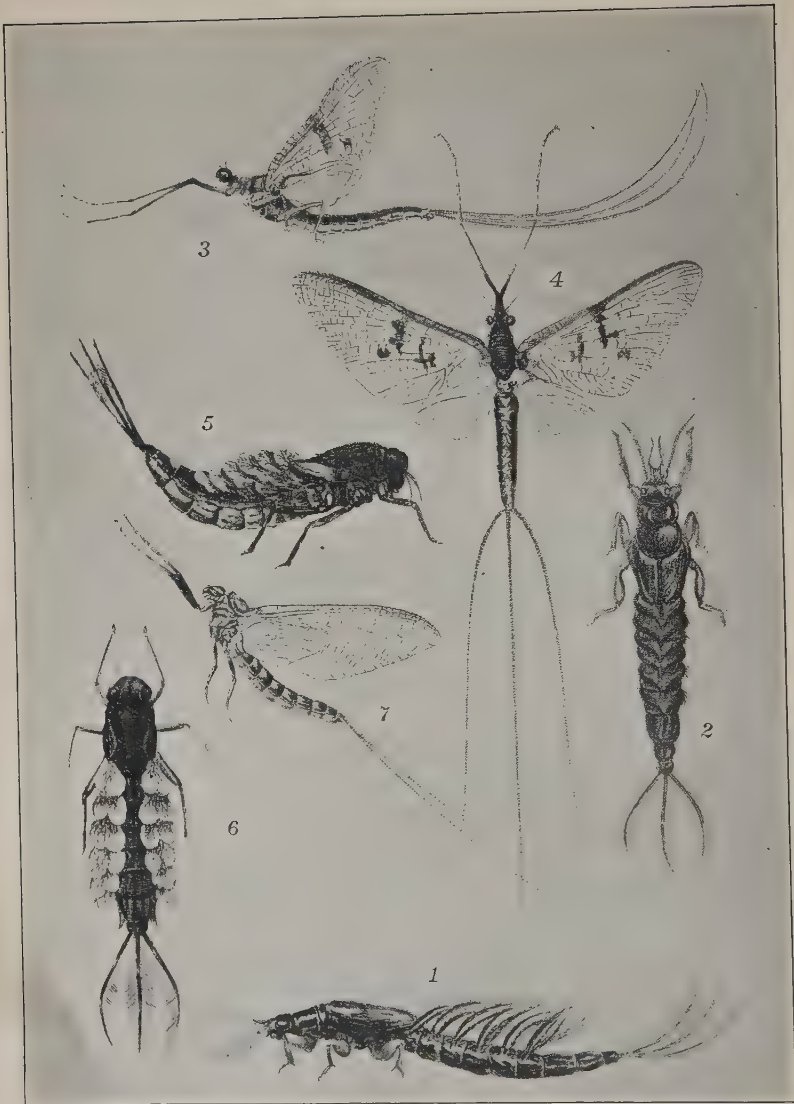

FIG. 123. May-flies (*Ephemera varia* Etn.)

1, *2*, side and back views of nymph; *3*, *4*, side and back view of adult male (*Siphlurus alternatus* Say); *5*, *6*, side and back view of nymph; *7*, side view of adult male. (After Needham)

larger with each successive molt, until the water nymph sheds its skin for the last time, the gills and mouth-parts are left behind, and the winged May-fly comes forth. After flying a short distance it alights and again sheds its skin, a thin layer coming off from all parts of the body, even from the wings, which process must certainly be the "exception which proves the rule," for no other insects ever molt after becoming winged. The eggs are now deposited by the females either on the surface of the water or on stones beneath the surface, and in a few hours, or at most in a day or two, the adults die. The nymphs live from one to three years, according to the species, and form an important item of the food of fishes, but are otherwise of no economic importance.

FIG. 124. A stone-fly (*Pteronarcys regalis*). (Slightly reduced)

(After Newport, from Folsom)

The stone-flies (order *Plecoptera*)[1] are quite similar to the May-flies in their general habits, but quite unlike them in appearance. The hind-wings are much larger than the fore-wings and are folded beneath them in plaits when at rest. The mouth-parts of the adults are of the biting type, but are often poorly developed. The antennæ are rather long and slender, and usually there are two many-jointed cerci extending from the tip of the abdomen. The nymphs live beneath stones in swift-running streams and are from one

FIG. 125. A stone-fly nymph

(After Comstock)

[1] From *plecos* (plaited), and *pteron* (wing).

half to one and one half inches long; with their long legs, and antennæ and cerci projecting from either end, they have a very distinctive appearance, as shown in Fig. 125. Behind each leg is a clump of hairlike tracheal gills, very similar to those found on the dobson, through which they breathe. They are a favorite food of fishes, particularly of brook trout, and make excellent bait. When full grown the nymphs crawl upon rocks or reeds and transform to the adult stone-flies, the old skins being frequently found in such places. The adults are dull grayish or brownish, the more common forms being from one to one and one half inches long, and are usually found on foliage in shady places along streams. They probably take no food and live only long enough to lay the eggs. Some of the smaller species, about one fourth of an inch long, of a blackish color, are often common on snow in early spring, and frequent windows at that time.

Fig. 126. A damsel-fly (*Lestes uncata* Kirby), female

(After Needham)

The dragon-flies and damsel-flies (order *Odonata*) are readily recognized by their long, narrow, powerful wings, which are about equal in size and on the front margin of which is a little notch and strong cross vein, called the *nodus*. The mouth-parts are well developed and are of the biting type, both larvæ and adults being predacious upon other insects. The dragon-flies and damsel-flies are distinguishable both as adults and as nymphs. The adult damsel-fly holds the wings vertically over the back when at rest, like a butterfly; the fore and hind wings are similar in shape, and the nymphs have three long, leaflike tracheal gills projecting from the tip of the abdomen. The dragon-flies hold their wings horizontally when at rest, the hind wings are usually much broader at the base, and the

FIG. 127. Nymph of a damsel-fly (*Lestes* sp.). (Twice natural size)

Showing the three leaflike tracheal gills at the tip of the abdomen. (After Kellogg)

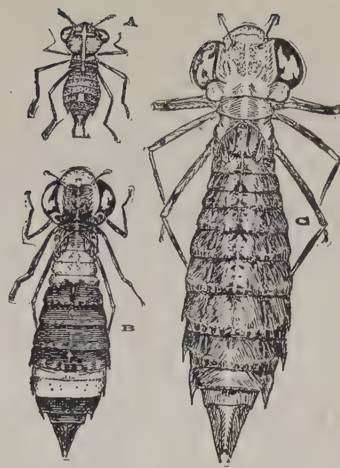

FIG. 128. Early stages of nymph of a dragon-fly (*Anax junius* Dru.). (All enlarged)

Showing changes of color pattern: *A*, newly hatched; *B*, one fourth grown; *C*, one half grown. (After Needham)

FIG. 129. A dragon-fly and its development

Nymphs feeding at *1* and *3*, showing extension of underlip or mask and the way prey is grasped by it; *2*, mature nymph ready to molt; *4*, skin of nymph from which the adult (*5*) has emerged. (After Brehm)

nymph has five converging, spinelike appendages at the tip of the abdomen. The dragon-flies are among the swiftest fliers, darting here and there after small flies, and are important enemies of mosquitoes. They have received many local names, such as darning needles, snake doctors, etc., with which are connected many curious superstitions of sewing up people's ears, bringing snakes to life, etc., of which they are of course entirely innocent. They are usually dark colored, though often brilliantly marked with metallic blue, green, and red. The damsel-flies are more slender-bodied and fly lazily about. The eggs are laid in the water or fastened to aquatic plants. From them hatch the little long-legged nymphs which may be found browsing in the ooze and mud of any pond. Dark-colored, flat, and spiny, they are hardly distinguishable from the débris of the bottom. They have a peculiar underlip, remarkably extensile, with two powerful hooks at the tip, which, when thrown forward from the head, grasps the unsuspecting prey. When drawn in, the labium covers the front of the face and gives the nymph an exceedingly comical appearance, with its large, shrewd eyes on either side. The nymphs of the damsel-flies breathe through the tracheal gills at the tip of the abdomen, but the dragon-fly nymphs have a peculiar way of drawing water into the rectum, whose walls are very thin and lined with numerous trachea, so that the air in the trachea is purified through the wall of the rectum as if it were a tracheal gill. The water from the rectum may be ejected forcibly, so as to drive the nymph suddenly forward. When full grown the nymph crawls up on a reed or plant

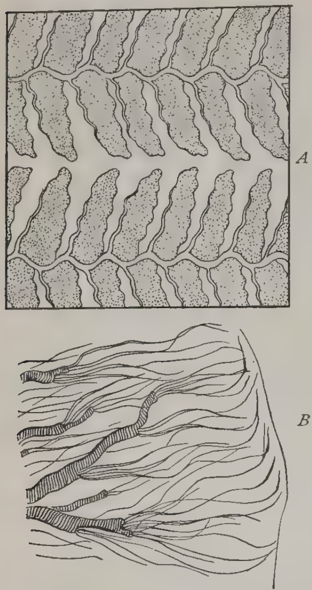

FIG. 130. *A*, part of two rows of respiratory folds from cuticular lining of rectum of dragon-fly nymph (*Æschna*). The shaded parts are abundantly supplied with tracheal tubes, as shown at *B*, a small part of one leaflet highly magnified, showing many fine tracheal branches

(Redrawn from Miall)

FIG. 131. Development of a dragon-fly (*Leucorhinia glacialis* Hagen)

1, two nymphs on the bottom of the pond; *2*, the empty nymphal skin left clinging to a branch after transformation; *3*, the adult female; *4, 5*, back and side views of the adult male (After Needham)

and molts for the last time, the adult quickly flying away and leaving the cast skin, which is often found intact and gives an excellent idea of the structure of the nymph, so remarkably unlike the adult in both form and habit.

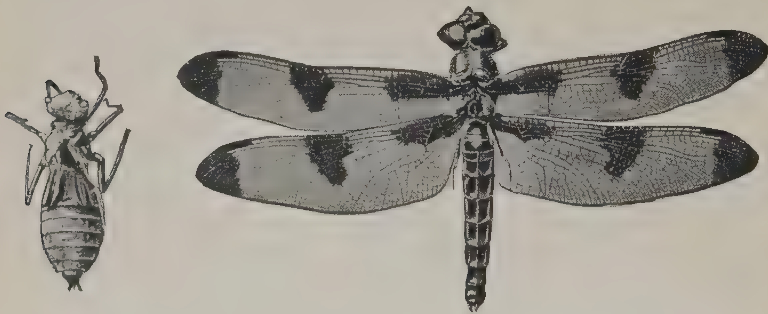

FIG. 132. Dragon-fly (*Libellula pulchella*). (Slightly reduced) *A*, last nymphal skin; *B*, adult. (After Folsom)

SUMMARY OF THE NERVE-WINGED INSECTS AND THEIR RELATIVES

A. With complete metamorphosis:

Order *Neuroptera*. Wings equal; numerous cross veins.

The dobsons (*Sialidae*). Larvæ aquatic.

The aphis-lions (*Chrysopidae*). Feed on aphides, etc.

The ant-lions (*Myrmeleonidae*). Larvæ make pits in soil.

Order *Mecoptera*. Scorpion-flies. Elongate head, and tip of abdomen fang-like. Larvæ live underground.

Order *Trichoptera*. Caddis-flies. Wings with few cross veins and clothed with hairs. Larvæ live in water, many being case bearers.

B. With incomplete metamorphosis (*Pseudoneuroptera*):

Order *Ephemerida*. May-flies. Fore-wings much larger; mouth-parts rudimentary. Nymphs aquatic.

Order *Plecoptera*. Stone-flies. Hind-wings larger and plaited beneath the fore-wings when at rest. Nymphs aquatic.

Order *Odonata*. Dragon-flies and damsel-flies. Wings about equal in size, with a nodus on the front margin. Nymphs aquatic.

CHAPTER X

THE WHITE ANTS, BOOK-LICE, AND BIRD-LICE (*PLATYPTERA*)

Characteristics. Insects with two pairs of delicate, membranous wings equal or the hind pair smaller, and with the principal veins few and simple, or entirely wingless; mouth-parts, mandibulate; body, flattened; prothorax, broad; metamorphosis, incomplete.

The Platyptera (from *platys*, "flat," and *pteron*, "a wing," alluding to the wings of the white ants, which lie flat on the back when at rest) include three groups, which are often considered as separate orders and are quite distinct in appearance and habits; but may well be placed in a single order based upon the structural characters given above. When present the wings are never net-veined, and the book-lice and bird-lice are wingless. The body is usually flattened and the prothorax is usually well-developed and distinct.

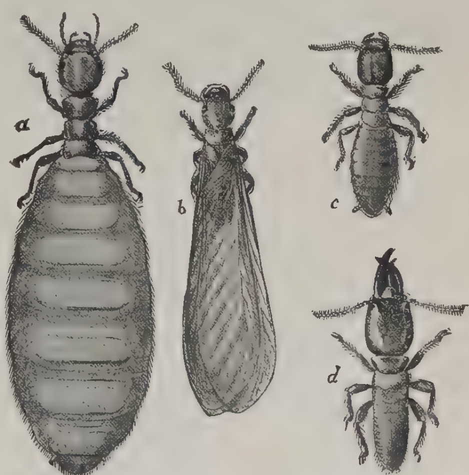

FIG. 133. White ants, or termites. (Enlarged) *a*, queen; *b*, male; *c*, worker; *d*, soldier. (After Jordan and Kellogg)

The white ants (*Termitidae*) are well-known inhabitants of fallen logs and decaying wood, and are readily mistaken for ants by the casual observer. The light yellowish color and the fact that the abdomen is broadly joined to the thorax, with no toothed constriction, as in the true ants, easily distinguish them. Though entirely unrelated to the true ants, they have a very similar social organization, with several distinct castes, of which only the so-called

kings and queens are winged. The wings are long and narrow, somewhat leathery in texture, and are furnished with numerous but somewhat indistinct veins, are about equal in size, and are laid flat on the back when at rest. They have well-developed biting mouth-parts, the mandibles of the soldiers projecting well forward of the huge head. They are most abundant in the tropics, where they are serious pests of all kinds of woodwork, mining into foundations, posts, furniture, and whatever happens in their way. The nests of the tropical species are often of large size, forming mounds sometimes twelve feet high, or huge, roundish masses several feet thick attached to trees. But one species (*Termes flavipes*)

FIG. 134. White ants' nest on trunk of tree (at arrow) in Cuba

(Photograph by Slingerland)

FIG. 135. *Psocus lineatus*. (Much enlarged)

(After J. B. Smith)

is common throughout the United States; it is usually found in old logs and stumps, but sometimes establishes its nests beneath

buildings, whose wooden foundations are then attacked and often so mined as to necessitate their removal. Such instances are more common in the South, but even in the North porch timbers are often attacked, and now and then the white ants invade a building and thoroughly tunnel the studding and even the lathing. The workers of both sexes are wingless, of a dirty white color, and busy themselves in building their nests, caring for the young termites, and securing food for the whole colony. The soldiers are also of both sexes, wingless, and resemble the workers, except that the heads are of immense size, being frequently as large as the rest of the body, and bear very strong mandibles, which form effective weapons. The kings and queens are really merely fathers and mothers, for they produce the colony but do not rule it. In early summer the kings (males) and queens (females) swarm forth from the nest and, after a short flight, shed their wings. Individual males and females now mate and are ready to start a new colony, but unless they are found and established by some workers they perish, and thus only few of them ever survive. If a pair are fortunate enough to be discovered by some workers, they are provided with food and are imprisoned in a circular cell. The queen now commences to develop eggs, and her body enlarges enormously, finally becoming nothing but a huge sack, often six inches long, filled with eggs. She is fed by the workers, who carry away the eggs and rear the young, which resemble the adults in general form. Thus the domestic economy of these colonies is hardly less interesting than that of the true ants.

FIG. 136. A psocid (side view), showing position of wings at rest. (Thirteen times natural size)

(After Kellogg)

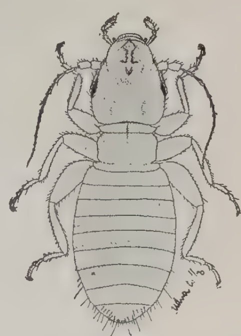

FIG. 137. A wingless book-louse (*Atropos* sp.). (Greatly enlarged)

(After Kellogg)

Book-lice. In neglected libraries or in old books which have been stored are to be found the tiny book-lice (*Psocidae*) which feed upon the paper bindings. They are exceedingly wise-looking little insects when examined with a lens, having all the appearance of being

adapted to their surroundings. Other members of this family, called psocids, are winged and look much like large plant-lice. The wings are of a dusky color, have a very characteristic venation, and are held roof-shaped over the back. Psocids feed on lichens and decaying wood and are frequently found in large masses on fences or tree trunks, where they are suspected of doing mischief, but they are entirely harmless and need not be disturbed.

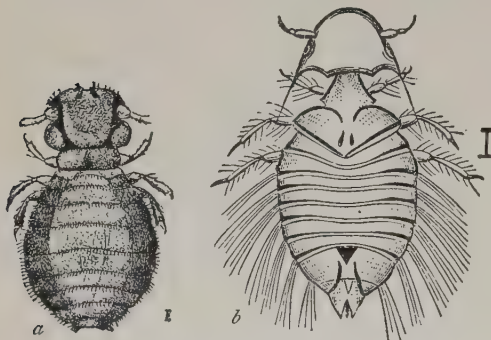

FIG. 138. Biting lice (*Mallophaga*). (Greatly enlarged)
a, turkey-louse (*Goniodes stylifer* Nitsch) (after Cuvier); *b*, the biting dog-louse (*Trichodectes latus* Nitsch) (after Denny). (From Osborn, United States Department of Agriculture)

The biting bird-lice (***Mallophaga***) are curious looking, wingless parasites which infest the feathers of poultry and birds, while some infest sheep and mammals. They have biting mouth-parts and feed on feathers, hair, and bits of skin, thus differing from the true lice (see p. 121), which have sucking mouth-parts with which they extract the blood. The flattened bodies and curiously shaped heads enable one to identify them readily. A dust bath, with a frequent thorough cleansing of the poultry house by spraying with kerosene and then whitewashing, will usually prevent serious annoyance to poultry.

CHAPTER XI

THE TRUE BUGS, APHIDES, AND SCALE INSECTS (*HEMIPTERA*)

Characteristics. Insects with four wings, except in the parasitic forms; fore-wings, thickened at the base, with membranous tips and overlapping on the back in the Heteroptera, but entirely membranous and sloping at the sides of the body in the suborder Homoptera; mouth-parts, suctorial; antennæ, few-jointed; metamorphosis, incomplete.

Ordinarily all insects or small, insectlike animals are called bugs by the uninitiated, but when the entomologist speaks of a

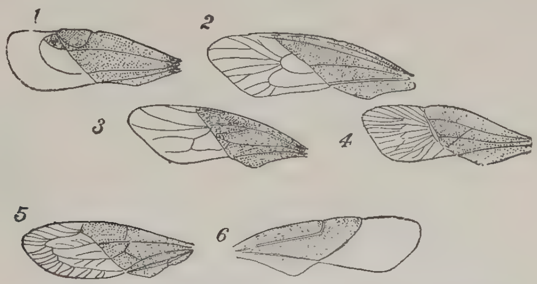

FIG. 139. Fore-wings of Heteroptera, showing thickened veins and arrangement of veins in membranous tip characteristic of various families

1, Capsidae; 2, Pyrrhocoridae; 3, Lygaeidae; 4, Coreidae; 5, Nabidae; 6, Acanthidae
(After Comstock)

bug he refers to an insect of the order *Hemiptera.* The insects of this order are readily recognized by the strong, pointed sucking beak which extends from the head between the legs, and in which are inclosed the other mouth-parts, as already described (see p. 17). They develop with an incomplete metamorphosis, as has been described for the squash-bug (p. 50), which is a good example of one group. The name of the order, *Hemiptera*, is derived from *hemi* (half) and *pteron* (wing), but is really applicable to only one suborder, the Heteroptera. The name *Heteroptera* has a similar significance, referring to the fore-wings, which have the

Fig. 140. A winged pea aphis, illustrating the uniform translucent, membranous texture and venation of the wings of the Homoptera. (Much enlarged)

basal half thickened and the tips membranous and overlapping, while the hind-wings are entirely membranous, so that the wings are unlike (*heteros*), and the beak arises from the front of the head. In the other principal suborder, the *Homoptera*, the wings are membranous throughout and slope at the sides of the body like a roof, both pairs of wings being alike (*homoios*), and the beak arises from the back of the head. A third suborder, the *Parasita*, are entirely wingless, degenerate forms which are parasitic on man and other mammals.

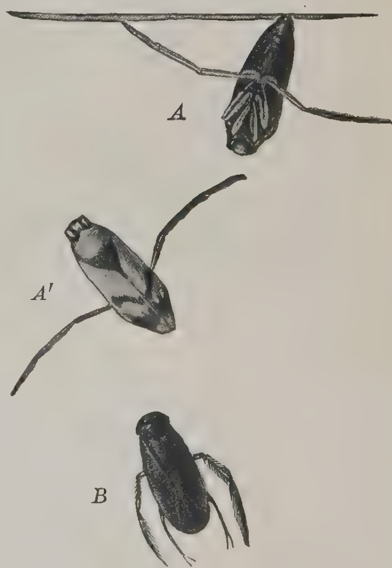

Fig. 141. Back-swimmers (*Notonecta*) *A*, *A′*, and water-boatman (*Corixa*) *B*. (Slightly enlarged)

(After Linville and Kelly)

Suborder Heteroptera

The aquatic bugs. Several families of true bugs inhabit our streams, ponds, and lakes. The water-boatmen (*Corisidae*) are from one fourth to one half an inch long, and of a brownish color, but appear like glistening silver as they dive through the water, carrying with them a thin coating of air which they breathe. Their near relatives, the back-swimmers (*Notonectidae*), differ in that they swim upside down on their backs, which are shaped like the keel of a boat instead of being flat. The water-scorpions

(*Nepidae*) are so called from the long tube extending from the tip of the abdomen, which is thrust to the surface of the water for breathing. They are elongate insects, with long legs, the front

FIG. 142. A water-scorpion (*Ranatra fusca*). (Enlarged)

(After Lugger)

pair being fitted for grasping their prey, and live on the stems of plants, which they closely resemble.

The giant water-bugs (*Belostomidae*) are probably better known to most boys as electric-light bugs, for with the advent of the arc light they have become very numerous on the streets on warm summer evenings. The largest are over two inches long and can inflict a painful wound with their strong beaks, which they use for preying upon other insects and small fish. These larger water-bugs, as well as the back swimmers, often become a serious pest where the artificial propagation of fish is attempted. Many of the females fasten their eggs to their own backs with a waterproof glue.

FIG. 143. The undulating back-swimmer (*Notonecta undulata*). (Twice natural size)

(After Weed)

Every one who has been fishing knows the water-striders (*Hydrobatidae*) which dart here and there over the surface and suddenly

FIG. 144. *A*, the giant water-bug or electric-light bug (*Belostoma americana*); *B*, the western water-bug (*Serphus* sp), male, with eggs deposited on its back by the female. (Natural size)

(After Kellogg)

FIG. 145. A water-strider (*Hygrotrechus remigus* Say). (Enlarged)

(After Lugger)

FIG. 146. The masked bedbug hunter (*Opsicoetus personatus* Linn.), adult and dust-covered nymphs. (Enlarged)

(After Brehm)

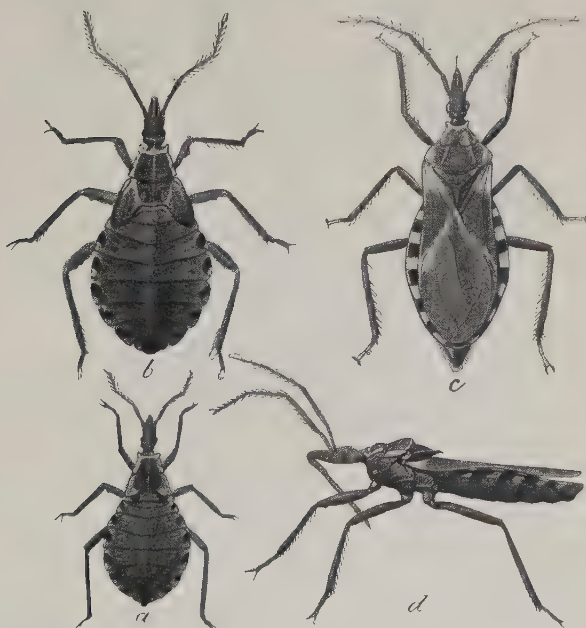

FIG. 147. The big bedbug or bloodsucking cone-nose (*Conorhinus sanguisuga*). (Enlarged)

a, *b*, last stages of nymphs; *c*, *d*, adults. (After Marlatt, United States Department of Agriculture)

leap for some unwary midge or other small insect. They usually occur together in some numbers, and some kinds have been seen on the ocean hundreds of miles from land.

All of the aquatic bugs are predacious upon other insects or upon small aquatic animals or fish, and may therefore be either beneficial or injurious, according to the nature of the food.

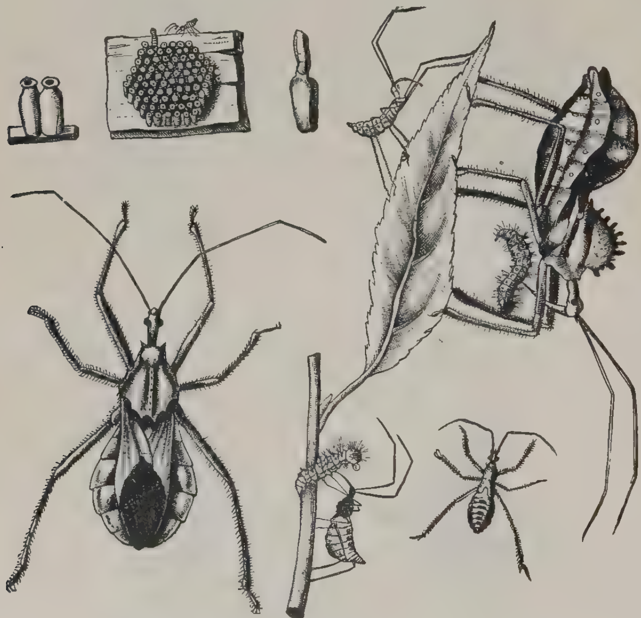

FIG. 148. The wheel-bug (*Prionidus cristatus* Linn.), eggs, nymphs, and adults (After Glover, United States Department of Agriculture)

The predacious bugs. Several terrestrial families are predacious and may be conveniently considered together. The assassin-bugs (*Reduviidae*) are well named in this respect. They feed on soft-bodied insects, but unfortunately are not discriminating in their choice, so that frequently beneficial insects are destroyed in large numbers. They are more common in the South, where one of the largest species is known as the wheel-bug (*Arilus cristatus*) from the large hump, like a cogwheel, on the back. In the North are several species, commonly found around houses, one of which is

known as the masked bedbug hunter, from the habit of the nymph of covering itself with dust and rubbish so as to be thoroughly concealed as it waits in dusty corners for its prey. This species, with

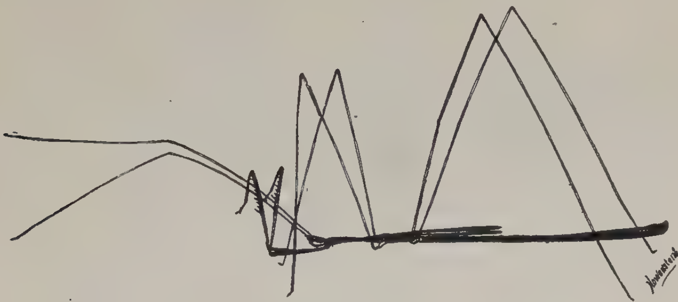

FIG. 149. Thread-legged bug (*Emesa longipes* De G.)
(After Lugger)

another (*Melanolestes picipes*), was the subject of considerable newspaper notoriety a few years ago as the kissing bug, since it not infrequently attacks the lips of people while they are asleep. The

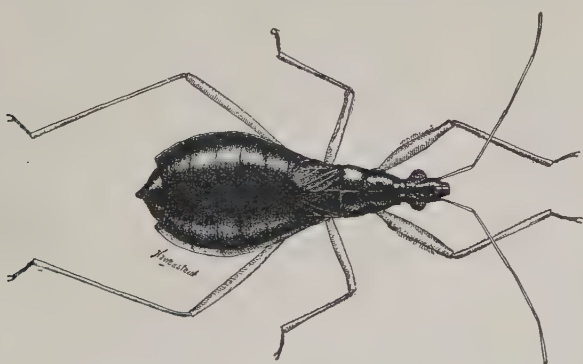

FIG. 150. A damsel-bug (*Coriscus subcoleopterus* Kby.)
(After Lugger)

thread-legged bugs (*Emesidae*) are well described by their name, all of the legs being long and threadlike. The forelegs are fitted for grasping the prey, resembling those of the mantis, and the antennæ are bent so as to simulate forelegs. They are sometimes found

around barns and sheds, where they are said to rob spiders' webs of their prey. The damsel-bugs (*Nabidae*) frequent flowers and vegetation, feeding on any small insects they may conquer. The blond damsel-bug (*Coriscus ferus*) is of a light yellowish color, with numerous brown dots, and is often taken in sweeping grass with a net. The other most common species, the black damsel-bug (*Coriscus subcoleoptratus*), receives its specific name from the fact that at first glance it closely resembles a beetle, the wings being mere rudiments and the body shining black, with yellowish legs.

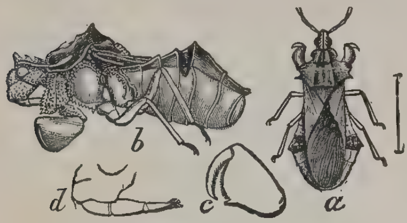

FIG. 151. *Phymata wolfii*. (Enlarged)

a, *b*, side and back views; *c*, front leg; *d*, beak. (After Riley, United States Department of Agriculture)

A single species (*Phymata wolfii*) of the ambush-bugs (*Phymatidae*) is found very commonly lurking in the flowers of the goldenrod. It is yellowish or greenish in color, with a broad black band across the abdomen, and the front legs are strongly developed for grasping, so that it is able to overpower much larger insects. The bedbug and its relatives the flower-bugs (*Acanthidae*) are also predacious. The former is too well known to need description, and another similar wingless form attacks swallows, bats, pigeons, etc. The flower-bugs have well-developed wings and lurk in blossoms, where they attack small insects.

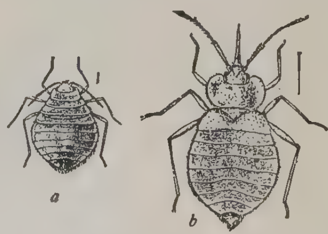

FIG. 152. Bedbug. (Enlarged)

a, nymph; *b*, adult, with outstretched beak

The stink-bugs, or shield-shaped bugs (*Pentatomidae*), are a large family readily distinguished by their shape, and, with two or three nearly related but small and unimportant families, may be distinguished from other terrestrial Heteroptera by having antennæ of five segments instead of four. The term "stink-bug" is not definite, for many other families have very characteristic "buggy" odors, but as these insects frequently attack berries, which retain their odor, we have become better acquainted with this disagreeable characteristic

in their case,—hence the name. They have small heads with broad, prominent shoulders, and the large, triangular scutellum occupies

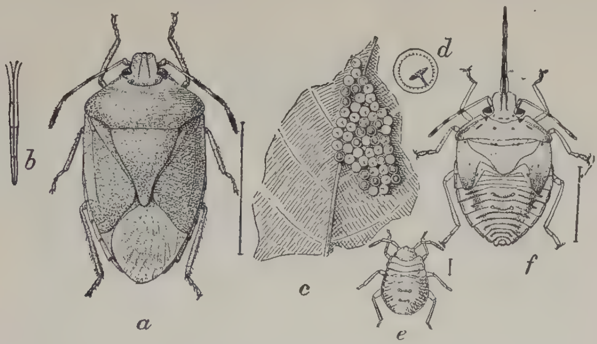

FIG. 153. The green soldier-bug (*Nezara hilaris*). (Enlarged)

a, adult; *b*, beak; *c*, eggs; *d*, single egg; *e*, young nymph; *f*, last stage of nymph. (After Chittenden, United States Department of Agriculture)

the center of the back between the wings, which are rounded at the tip of the abdomen, giving the whole body a characteristic shield-shaped appearance. From an economic standpoint the family is divided, some species being predacious upon other insects and others being serious crop pests, while some have both habits, as circumstances may offer food of one kind or the other. The predacious species are commonly known as soldier-bugs and feed mostly upon caterpillars. The common green soldier-bug (*Nezara hilaris*) feeds upon the larvæ of the Colorado potato-beetle, cotton-leaf caterpillars, and other injurious forms, but unfortunately it not infrequently attacks cotton bolls, ripening oranges, and various fruits and vegetables, doing considerable injury by sucking the juices and causing malformations. The spined soldier-bug (*Podisus spinosus*) is a common enemy of leaf-eating caterpillars, such as the tussock moths, gypsy and brown-tail moths, and of many soft-bodied grubs, like those of the potato-beetle. Other species, like the harlequin cabbage-bug (*Murgantia histrionica*), which is

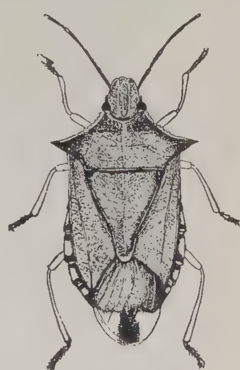

FIG. 154. Spined soldier-bug (*Podisus spinosus*). (Enlarged)

(After Lugger)

black with numerous red or orange markings and is one of the most serious pests of cabbage throughout the South, feed wholly on vegetation. Small green species (*Thyanta custator* and *Pentatoma sayi*) have done serious injury to grain and forage crops in Texas and Colorado in recent years. The little Negro-bugs of a nearly related family (*Corimelaenidae*) are jet-black and have the

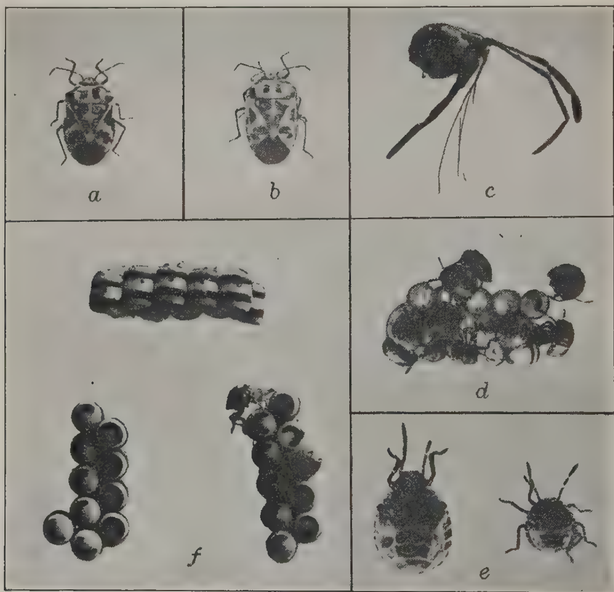

FIG. 155. The harlequin cabbage-bug

a, *b*, adults (natural size); *c*, side view of head with mandibular and maxillary setæ out of beak; *d*, eggs with newly hatched young; *e*, nymphs; *f*, egg masses with one egg hatching and newly hatched nymph on lower right mass

scutellum enlarged so that it covers nearly the whole abdomen and gives the bug the appearance of a beetle, for which it is frequently mistaken by a beginner. They infest various plants and often injure berries by imparting their disagreeable odor, as do the stink-bugs.

Plant-bugs. The remaining families of Heteroptera feed entirely on vegetation and may for convenience be grouped together as plant-bugs. They are all more or less elongate in form, with slender legs, and antennæ about half the length of the body. The families

are most readily distinguished by the venation of the front wings, several of which are shown in Fig. 139, p. 107.

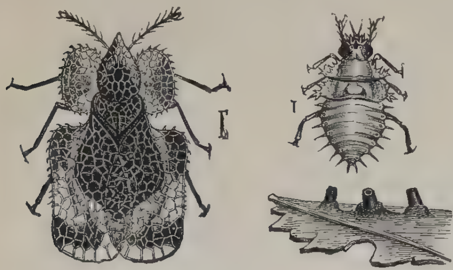

FIG. 156. Lace-bug (*Corythuca arcuata* Say), adult, eggs, and nymph

(After Comstock, United States Department of Agriculture)

The lace-bugs (*Tingitidae*) are found commonly on the leaves of basswood, hawthorn, and quince, occasionally injuring the latter. "One glance at the fine white meshes that cover the wings and spined thorax is sufficient," says Professor Comstock, "to distinguish them from all other insects, for these are the only ones that are clothed from head to foot in fine white Brussels net." They are small insects, about the size of plant-lice, and suck the juices of the leaves. The eggs are covered with a sticky substance and look like fungi on the undersurface of the leaf.

The leaf-bugs (*Capsidae*) form the largest family of Heteroptera, having over two hundred fifty species in this country. One of the most common species is the tarnished plant-bug (*Lygus pratensis*). This is yellowish- or greenish-brown in color, about one fourth of an inch long (Fig. 157), and attacks a great variety of plants, being injurious to nursery trees, sugar beets, strawberries, and various vegetables and flowering plants, causing the tips of plants like the dahlia and potato to

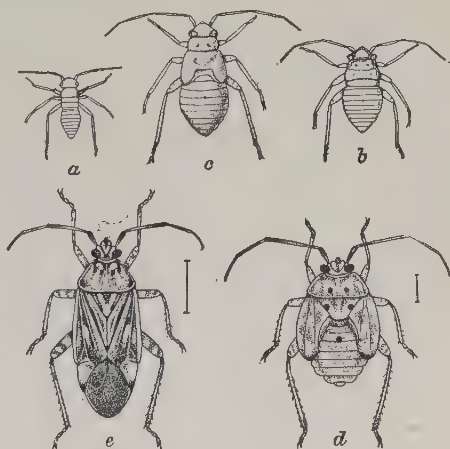

FIG. 157. Tarnished plant-bug. (About four times natural size)

a, *b*, *c*, *d*, four stages of nymphs; *e*, adult bug. (After Forbes and Chittenden)

wither beyond the point where the little bug has inserted its beak. The four-lined leaf-bug (*Poecilocapsus lineatus*) is yellowish or

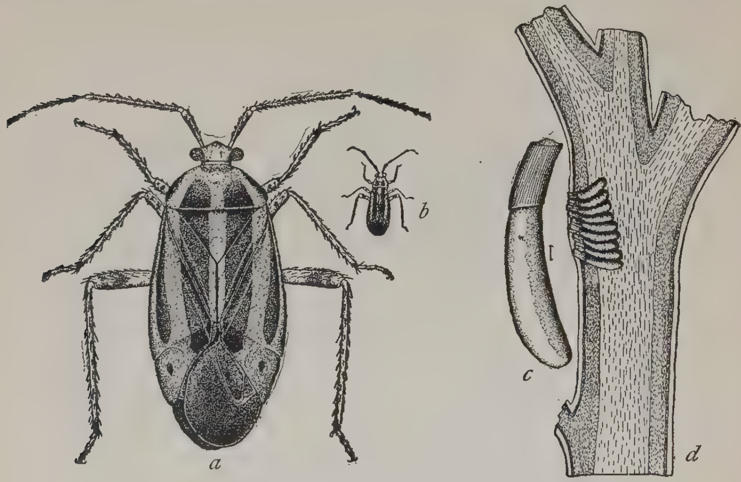

FIG. 158. The four-lined leaf-bug

a, adult (enlarged); *b*, adult (natural size); *c*, single egg (greatly enlarged); *d*, lengthwise section of stem, showing eggs in position (enlarged). (After Slingerland)

greenish, with four black stripes (Fig. 158), and is often a serious enemy of currants, laying its eggs in the stalks and thus killing the tips. The cotton leaf-bug is found throughout the country on

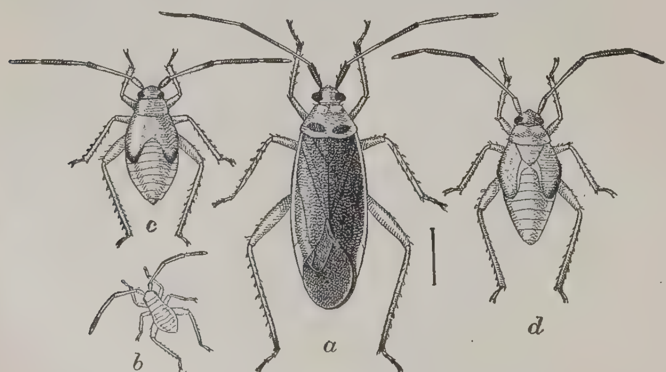

FIG. 159. Cotton leaf-bug (*Calocoris rapidus*)

a, mature bug; *b*, young nymph; *c*, fourth stage of nymph; *d*, fifth stage of nymph (Authors' illustration, United States Department of Agriculture)

various flowers and is sometimes an enemy of the sugar beet, but in the South it is best known for causing the cotton squares to drop and producing black spots and distortions of the bolls. It is dark

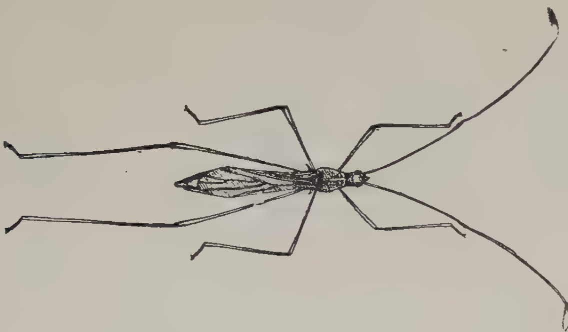

FIG. 160. A stilt-bug (*Jalysus spinosus* Say). (Enlarged) (After Lugger)

brown, with a narrow yellow border, the prothorax being yellow and red with two black spots. Nearly related is the red-bug family (*Pyrrhocoridae*), named after the red-bug, or cotton-stainer (*Dysdercus*

FIG. 161. The chinch-bug. (Much enlarged)

Adult at left; *a*, *b*, eggs; *c*, newly hatched nymph; *d*, its tarsus; *e*, *f*, *g*, second, third, and fourth stages of nymph; *h*, leg of adult; *j*, tarsus of same; *i*, proboscis, or beak. Hair lines indicate natural size. (After Webster and Riley)

suturellus), an insect of a reddish color, with pale yellow stripes, with habits very similar to the one last mentioned, staining the cotton where it punctures the bolls. Though common, it is by no means a serious pest of cotton, but is often injurious to ripening

oranges. The family is a small one of relatively large, bright-colored bugs, with few species in the North. The stilt-bugs (*Berytidae*) are well named from their long, stiltlike legs. They resemble the thread-legged bugs in this respect, but are much smaller, being only about one third of an inch long. Only two species are known in the United States; these frequent the undergrowth of woodland and pastures. The chinch-bug is the best-known example of one of the largest families (*Lygaeidae*), with nearly two hundred species in this country. The chinch-bug is about one sixth of an inch long, of a jet-black color, with the fore-wings white with a distinct triangular black spot at the middle of the outer margin.

FIG. 162. The false chinch-bug (*Nysius ericae* Schill.). (Much enlarged)

a, injured leaf; *b*, last stage of nymph; *c*, adult. (After Riley)

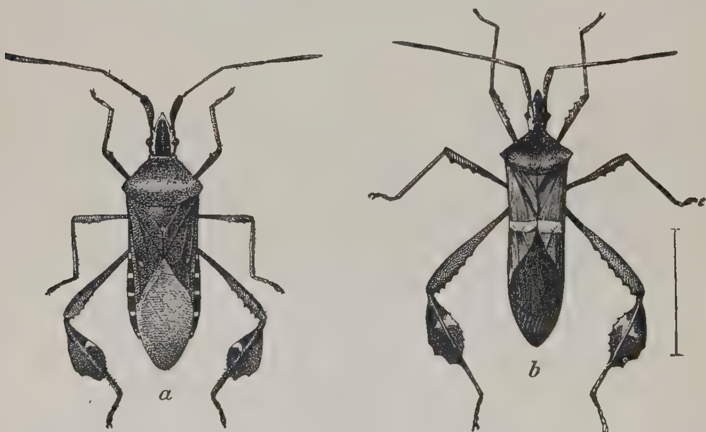

FIG. 163. *a*, the northern leaf-footed plant-bug (*Leptoglossus oppositus*); *b*, the banded leaf-footed plant-bug (*Leptoglossus phyllopus*). (Twice natural size)

(After Chittenden, United States Department of Agriculture)

The young stages are red but become gray or blackish as they grow older. It is found in all parts of the United States, but has been most seriously injurious in the Mississippi Valley.

The squash-bug and its relatives form another large family (*Coreidae*) of some two hundred species, of which the common squash-bug (*Anasa tristis*), which we have already considered (p. 50), is the best-known example. In the middle and southern states there are several nearly related species which have the hind tibia flattened and expanded somewhat like a leaf, and are known as leaf-footed plant-bugs. The box-elder bug (*Leptocoris trivittatus*) is a common species throughout the Mississippi Valley and Great Plains, where it is a serious enemy of the box elder, which is planted largely for shade. It is blackish, with three bright red lines on the prothorax, and with fore-wings having edges and veins of a dingy red.

FIG. 164. Box-elder bug (*Leptocoris trivittatus*). (Twice natural size)

(After Kellogg)

SUBORDER PARASITA

As their name indicates, the members of this suborder are parasites upon man and other mammals, being commonly known as *lice*. They may well be called the true lice, or sucking lice, to distinguish them from the bird-lice (*Mallophaga*), plant-lice (*Aphididae*), and other insects commonly called lice. They are small, soft-bodied, wingless insects, with a stout, unsegmented beak, either without eyes or with only simple eyes, and the tarsi bear but a single claw, all of these characters indicating a degenerate group. The head-louse infests the hair of man, and the body-louse, or grayback, as soldiers term it, lives in and lays its eggs in the seams of clothing. The general appearance, greatly enlarged,

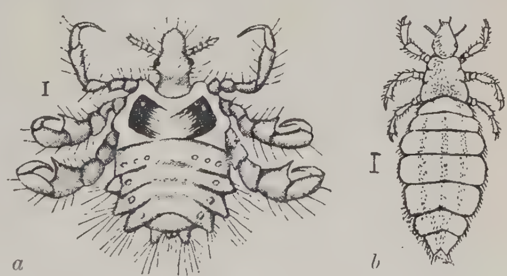

FIG. 165. Sucking lice affecting man. (Greatly enlarged)

a, crab-louse (*Pthirius inguinalis* Leach); *b*, head-louse (*Pediculus capitis* De G.). (*a*, after Denny; *b*, after Packard; from Osborn, United States Department of Agriculture)

of these vermin is shown in Fig. 165. Similar species infest horses, cattle, and other domestic animals, as well as many wild mammals.

Suborder Homoptera

The cicadas (*Cicadidae*). The common dog-day harvest-fly (Fig. 166) is the best known example of this interesting family; and although we seldom see it, we are made aware of its presence on a hot summer day by the shrill calls answered back and forth from the tree tops. It is black and green in color, more or less powdered with white beneath. The most remarkable member of

Fig. 166. Dog-day harvest-fly (*Cicada tibicen*), female (After Lugger)

the family is the periodical cicada, often improperly called the seventeen-year locust, from its habit of appearing in immense numbers every seventeen years. It is of course entirely unrelated to the true locusts, or grasshoppers. The adults lay their eggs in the twigs of trees, often seriously injuring young fruit trees, as the twigs or stems die beyond the point of the egg puncture. The nymphs drop to the ground upon hatching and, burrowing into the earth, feed upon the roots of trees for sixteen years. The seventeenth year they emerge in immense numbers within a few days, crawl up the trunks of trees, fences, buildings, etc., and transform to the adults, which are blackish, with orange markings on the wings. For the next few weeks the air is filled with their shrill cries, and soon many affected trees turn brown as a result of

FIG. 167. Periodical cicada

a, adult; *b*, young nymph (enlarged); *c*, cast skin of full-grown nymph; *d*, side view of female to show beak, *e*, and ovipositor, *f*. (Natural size except *b*.) (After Marlatt and Riley, United States Department of Agriculture)

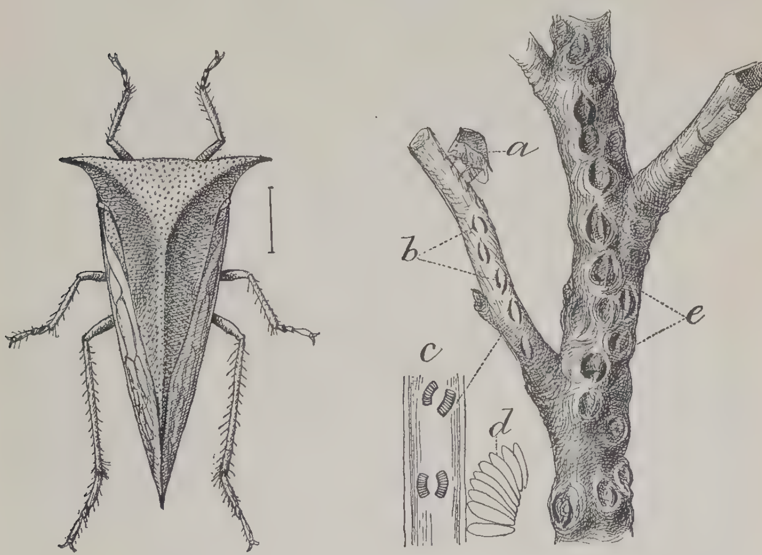

FIG. 168. Buffalo tree-hopper and twig of apple tree showing eggs and adult

Adult (enlarged) at left; *a*, adult (natural size); *b*, recent egg punctures; *c*, bark reversed with eggs in position; *d*, single row of eggs (enlarged); *e*, wounds of two or three years' standing on older limbs. (After Marlatt, United States Department of Agriculture)

their egg laying. The different broods have been carefully mapped, so that it is possible to foretell the appearance in any given locality where the insect occurs.[1]

Plant-hoppers. The next three families may be grouped together under the term "plant-hoppers," as they jump off suddenly when disturbed. They are small insects, usually not over one fourth of an inch long, and suck the sap from the leaves and stems of their food plants. The tree-hoppers (*Membracidae*) have been called the "brownie insects," for their bizarre shapes are often comically grotesque. The prothorax is prolonged back over the abdomen and is often produced forward or upward into horns or crests, as shown in Fig. 169. One of the most common species is the buffalo tree-hopper (*Ceresa bubalus*), which lays its eggs in the stems of weeds and young fruit trees, causing large knotty scars on the twigs. Another small brown species (*Enchenopa binotata*) is common on the bittersweet vine, the projecting prothorax looking exactly like a thorn on the stem. Few species of this family are sufficiently numerous to do serious damage.

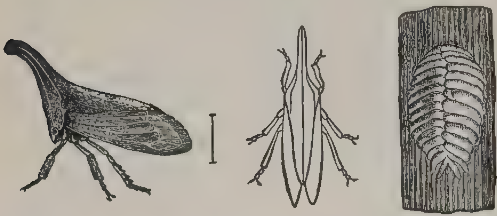

FIG. 169. The bittersweet tree-hopper (*Enchenopa binotata* Say). Adult (side and back views) and egg mass. (Much enlarged)

(After Lugger)

Here and there on weeds, grass, and tree foliage will be found a little mass of froth, within which may be found a small nymph, which is busily pumping the sap out of the plant, thus causing the froth which was formerly supposed to be voided by tree frogs and was termed "frog spittle," — hence the insects of this family

FIG. 170. Mass of spittle produced by the nymph of a frog-hopper, or spittle-insect

[1] See *Bulletin No. 71*, Bureau of Entomology, United States Department of Agriculture, for a very complete and interesting account.

(*Cercopidae*) are called "frog-hoppers" or "spittle-insects." Within this frothy mass the little nymph molts and grows and finally forms a little clear space about its body, around which the foam dries, forming a little chamber within which it transforms to the adult. Though very commonly in evidence, few of this family are injurious.

The leaf-hoppers (*Jassidae*) are among the most abundant of the Homoptera. Take a net and sweep back and forth in any meadow and you will secure hundreds of them, Professor Herbert Osborn having estimated that frequently over a million live on an acre of grassland. They are more slender than the two preceding families, from an eighth to a fourth of an inch long, and of a brownish, green, or red color, the green and red often being arranged in stripes, giving a very striking coloration. The grape leaf-hopper (*Typhlocyba comes*), commonly called the grape thrips (although it is not a true thrips), is one of the most serious enemies of the vine. In late summer the foliage will often be brown as a result of their work, and a slight jar will cause them to fly off in clouds. They are small yellowish hoppers, scarcely an eighth of an inch long and strikingly marked with red and black. A yellowish-green species, the rose leaf-hopper (*Empoasca rosae*), often does considerable injury to rose foliage, and a similar one, the apple leaf-hopper (*Empoasca mali*), is found on the apple and frequently becomes a serious pest in the nursery. The presence of these leaf-hoppers is always indicated by the numerous white cast skins of the nymphs clinging to the undersides of the leaves. Some species fly to lights in large numbers. They hibernate as adults, and the eggs are usually laid just beneath the surface of the leaf of the food plant.

FIG. 171. *Aphrophora 4-notata* Say, a common frog-hopper

(After Lugger)

FIG. 172. Three cotton leaf-hoppers, commonly called "sharpshooters." (Much enlarged)

a, *Aulacizes irrorata*; *b*, *Oncometopia undata*; *c*, *Oncometopia lateralis*. (Authors' illustration, United States Department of Agriculture)

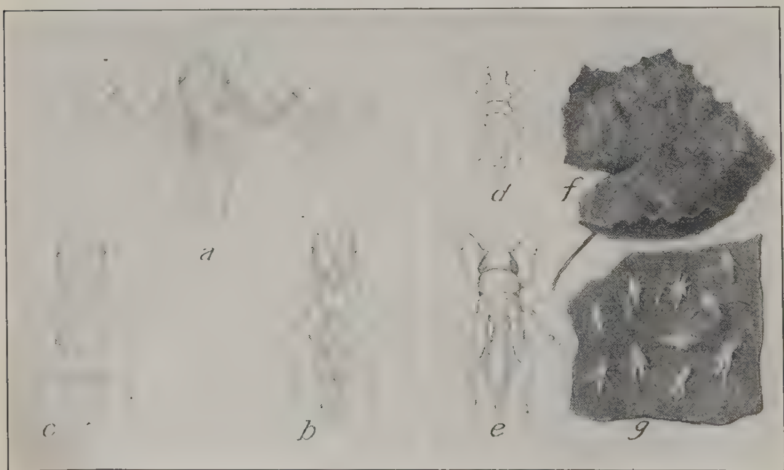

FIG. 173. Grape leaf-hoppers. (Much enlarged)

a and *b* are female and male of typical *comes* variety; *c* represents the *vitis* variety; *d*, newly hatched nymph; *e*, last stage nymph; *f*, injured leaf; *g*, cast skins. (After Marlatt, United States Department of Agriculture)

The psyllas, or jumping plant-lice (*Psyllidae*), look much like miniature cicadas, but are more nearly related to the true plant-lice, exuding sweet honey-dew like the plant-lice but differing from them in being very agile in the adult stage, giving a quick jump with their strong hind legs and flying off at the slightest disturbance, whereas the true plant-lice are exceedingly sluggish. The best-known example is the pear psylla (*Psylla pyricola*), the adult of which (Fig. 174, *a*) is not over a tenth of an inch long but which occurs in such enormous numbers that it sometimes entirely ruins large pear orchards by sucking the sap from the foliage. It has been most injurious in the Middle Atlantic States. It exudes a large amount of honey-dew,

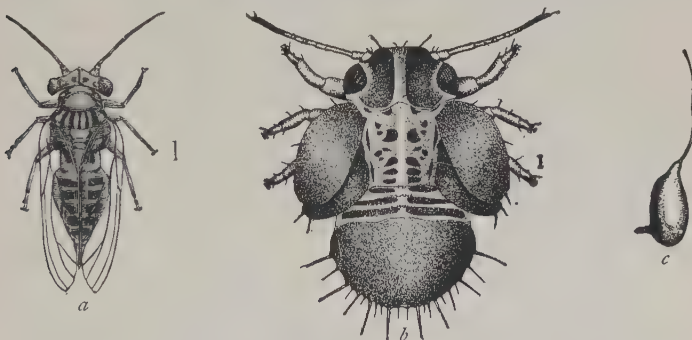

FIG. 174. The pear psylla. (Greatly enlarged, in different proportions)
a, adult; *b*, full-grown nymph from above; *c*, egg. (After Slingerland)

which covers the foliage and bark, on which grows a sooty black fungus which is a good indication of the presence of the pest.

The plant-lice, or aphides (*Aphididae*), are the most abundant and possibly the most destructive family of all the Hemiptera. Florists commonly call them green-flies, which term may refer to several species. Usually they are not over a tenth of an inch long, and the wingless forms are more or less pear-shaped, with long legs and antennæ, and the common forms have two tubes projecting from the abdomen, called honey-tubes. The vast amount of injury done by them is chiefly due to their remarkably rapid power of reproduction. During the summer the females will give birth to from fifty to seventy-five young during a week or two, which will become full grown in from one to two weeks. All of these

prove to be females, there usually being no males during the summer, and each gives birth to a similar number of young, the egg stage being passed within the body of the female and the young being born alive. Thus generation after generation is produced, and a simple arithmetical calculation will show that the resulting progeny must soon become sufficiently numerous to entirely destroy the vegetation from which the myriad little beaks are pumping out the sap.

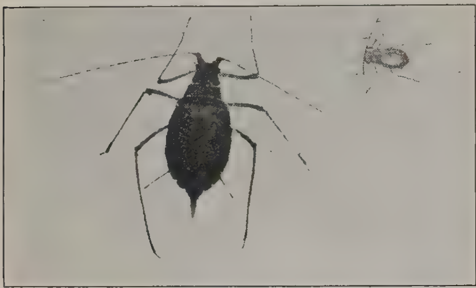

FIG. 175. Wingless female pea aphis and newly born young. (Enlarged)

In the fall true males and females usually appear, and eggs are laid which hatch in the early spring. Most species are wingless until the food supply commences to get short, when the next generation develops wings and migrates to new food plants. Many species have winged generations in the spring and fall, which

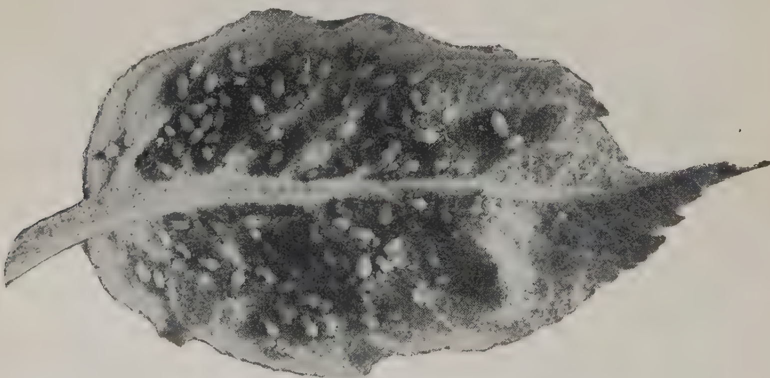

FIG. 176. Apple aphis, last stage nymphs of winged females on undersurface of apple leaf

migrate to and from the summer food plants to others upon which they feed in fall and spring, and upon which the winter eggs are deposited. Many plant-lice exude an abundance of a sweet liquid

called honey-dew, and are constantly attended by ants, which eagerly devour it. In the case of several species the ants care for them almost as if they were their domestic animals, and very commonly ants are responsible for carrying the aphides from one plant to another as the food supply becomes exhausted, as in the case of the melon aphis and the strawberry root-louse. Among the more common species are the common green apple aphis (*Aphis pomi*), the cabbage aphis, the pea aphis, which often destroys entire crops of garden peas in the Atlantic states, the green bug (*Toxoptera graminum*), which has recently been so injurious to grain crops in the southwest, the melon aphis, the rose aphis, the chrysanthemum aphis, and a host of others. The foliage of almost every plant is attacked by one or more species, and many of the most injurious attack the roots, as the corn root-aphis (*Aphis maidi-radicis*), which is one of the most serious corn pests in the Mississippi Valley. The grape phylloxera, an American species attacking the roots of the grape, was imported into Europe and soon became the worst enemy of the vine in France, where it has caused the loss of millions of dollars. Several species exude a cottony mass of wax over the body, so that they appear like a mold. Among these the woolly apple aphis is often seen on the leaves and on wounds and scars on the bark of apple trees, and a similar species covers the twigs of alder as if they were wound with cotton.

FIG. 177. Aphis eggs on twig. (Natural size) (After Weed)

FIG. 178. Tip of dock stem covered with black aphides

The scale insects (*Coccidae*). Some of the worst insect pests of the fruit orchard belong to the scale insects, which are so peculiar

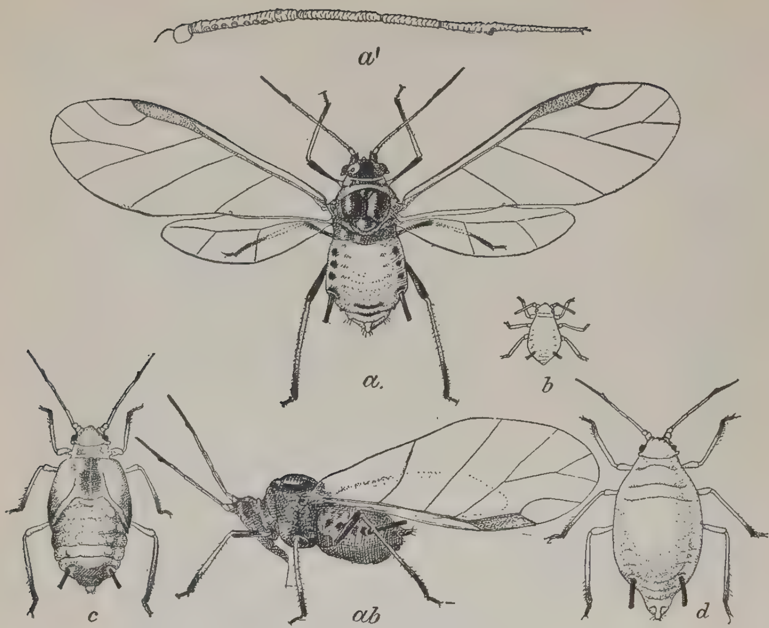

FIG. 179. Melon aphis. (Greatly enlarged)

a, winged female; *a'*, enlarged antenna of same; *ab*, dark female (side view), sucking juice from leaf; *b*, young nymph; *c*, last stage of nymph of winged form; *d*, wingless female. (After Chittenden, United States Department of Agriculture)

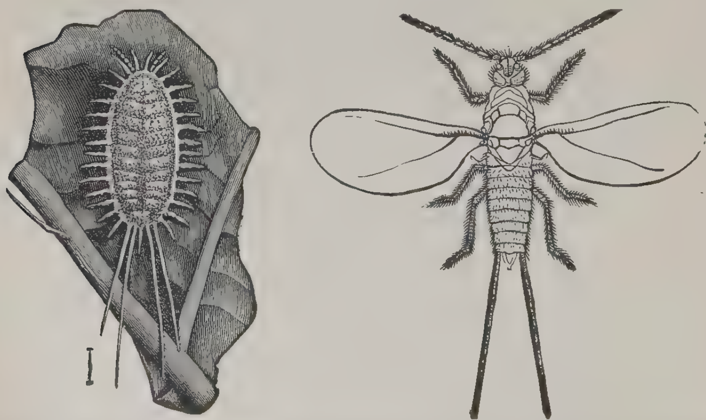

FIG. 180. Mealy-bug (*Dactylopius longifilis*), female and winged male. (Enlarged)

(After Comstock, United States Department of Agriculture)

in form that they would not be readily recognized as insects, were their complicated life histories not known. Three quite distinct

FIG. 181. The cochineal insect

a, on cactus; *b*, male; *c*, female (enlarged). (From Riverside Natural History)

groups may be readily distinguished. The mealy-bugs are frequently found on greenhouse plants, and are so named from their mealy covering of wax and the numerous white, waxy filaments

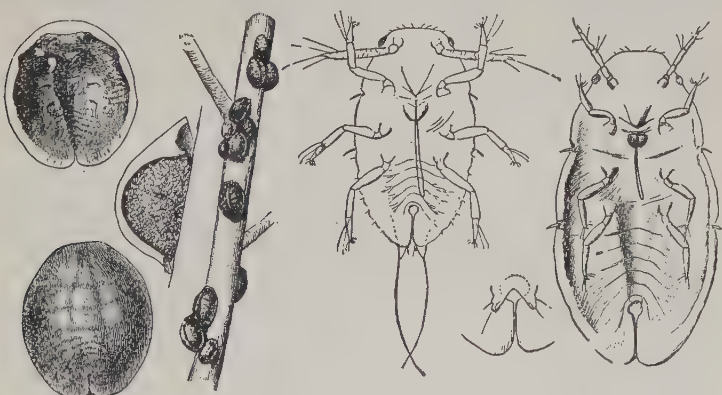

FIG. 182. The peach lecanium, or terrapin scale

Adults at left (much enlarged and natural size); young at center and unfertilized female at right (much enlarged). (After Howard, United States Department of Agriculture)

which are given off from their bodies. They are from an eighth to a quarter of an inch long, and move about slowly over the plant, retaining their legs throughout life. The soft scales include those

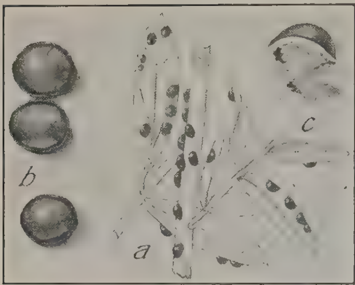

FIG. 183. The hemispherical scale (*Lecanium hemisphaericum* Targ.)

a, scales on olive (natural size); *b*, three female scales (considerably enlarged); *c*, female scale lifted from leaf, showing mass of eggs (enlarged). (After Marlatt, United States Department of Agriculture)

of the genus *Lecanium* and their near relatives, and are known as Lecaniums. They are usually of a brownish color, quite strongly convex (often ridged), and are soft and easily crushed, — hence the name. The upper surface of the female gradually hardens, and upon maturity she dies and the old skin forms the scale which covers the eggs laid beneath it. The Lecaniums occur upon various greenhouse plants such as crotons, upon the peach and plum, and upon citrous fruits. The cottony maple scale is a species common on maple shade trees and gives off a mass of cottony wax in which the eggs are laid.

FIG. 184. The cottony maple scale (Enlarged)

(After Comstock)

The armored scales are much smaller, flat, circular, or elongate in outline, and include our most common species. Upon hatching, the young scale insect crawls about for an hour or two and then settles down, inserts its beak in the leaf or bark, and henceforth the females remain in the same place. Soon waxy filaments commence to exude from the body, which mat down into a small scale covering the insect. When the skin is molted, it is added to the center or one end of the scale, which is gradually enlarged and assumes a characteristic shape. With the first molts the

FIG. 185. The oyster-shell scale on poplar twig

(Photograph by Weed)

female loses her legs and eyes, and the body becomes a mere mass of yellowish protoplasm with long, threadlike mouth-parts and a characteristic fringe of plates and hairs at the tip of the abdomen, by which the species is principally distinguished. They are named armored scales because the scales of this group are mere coverings and form no part of the insect. The scales of the males are much smaller than those of the females, and after the second molt the male goes into a true pupa stage (otherwise the Hemiptera have incomplete metamorphosis), the legs, wings, and antennæ being outlined, and with the next molt the adult male emerges from the scale and flies to fertilize the female. The adult males of all the Coccidae have but a single pair of

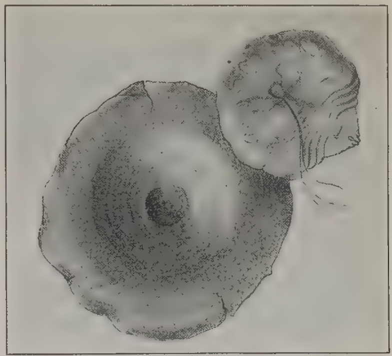

FIG. 186. Female San José scale, mature female insect removed from beneath it. (Greatly enlarged)

(After Alwood)

FIG. 187. *a*, winged male San José scale (much enlarged); *b*, young scale insect (enlarged 125 times)

(After Alwood)

wings, like the flies (*Diptera*), and bear long antennæ and usually one or two long processes from the tip of the abdomen. They are very small whitish or yellowish insects, and usually fly at night, so

that they are rarely seen unless reared from the scales. Among the most common of the armored scales are the oyster-shell bark-louse (so called on account of the resemblance of the brown scale to an oyster

FIG. 188. Peach twigs infested with San José scale. (Much enlarged)

At left, large mature female and small young scales are clustered in a groove of the twig. At right is shown a large female scale with the scale proper raised, showing the insect beneath. (After Britton)

shell), which is common on apple and several shade trees; the San José scale, possibly the most serious pest of fruit trees; the rose scale, common on roses, raspberries, and blackberry canes; and the various flat scales found on palms and other greenhouse and house plants.

Summary of the Hemiptera

I. Suborder *Heteroptera*. Wings unlike.

1. Aquatic bugs.
   The water-boatmen (*Corisidae*).
   The back-swimmers (*Notonectidae*).
   The water-scorpions (*Nepidae*).
   The giant water-bugs (*Belostomidae*).
   The water-striders (*Hydrobatidae*).
2. Predacious bugs.
   The assassin-bugs (*Reduviidae*).
   The long-legged bugs (*Emesidae*).
   The damsel-bugs (*Nabidae*).
   The ambush-bugs (*Phymatidae*).
   The bedbugs (*Acanthidae*).
   The stink-bugs, or shield-shaped bugs (*Pentatomidae*).
3. Plant bugs.
   The stink-bugs, or shield-shaped bugs (*Pentatomidae*).
   The lace-bugs (*Tingitidae*).
   The leaf-bugs (*Capsidae*).
   The red-bugs (*Pyrrhocoridae*).
   The stilt-bugs (*Berytidae*).
   The chinch-bugs (*Lygeidae*).
   The squash-bugs (*Coreidae*).

II. Suborder *Parasita*. Wingless parasites of animals.

III. Suborder *Homoptera*. Wings alike, translucent.

1. The cicadas (*Cicadidae*).
2. The plant-hoppers.
   The tree-hoppers (*Membracidae*).
   The frog-hoppers, or spittle insects (*Cercopidae*).
   The leaf-hoppers (*Jassidae*).
3. The psyllas, or jumping plant-lice (*Psyllidae*).
4. The plant-lice (*Aphididae*).
5. The scale insects (*Coccidae*).

CHAPTER XII

THE BEETLES (*COLEOPTERA*)

Characteristics. Fore-wings, horny or leathery, forming wing-covers (elytra), which meet in a straight line down the back; hind-wings, membranous, tips folded back under the wing-covers when at rest; mandibulate mouth-parts; metamorphosis, complete.

The hard wing-covers of this order are so characteristic that a beetle is commonly recognized as such, and they have given the

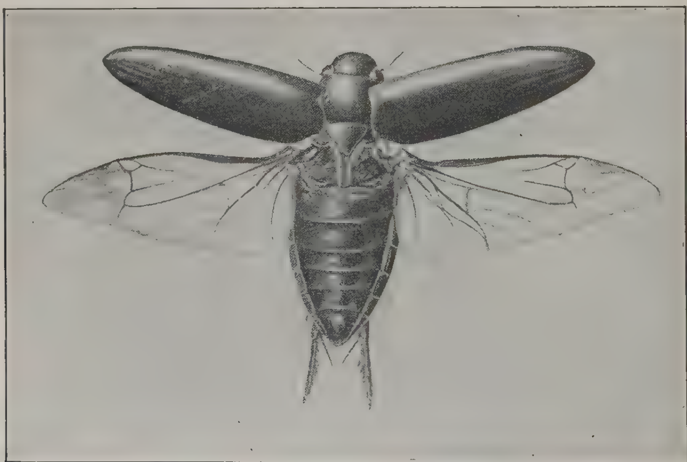

FIG. 189. A water-scavenger beetle with wing-covers and wings expanded as when in flight. (Natural size)

(After Folsom)

order its scientific name, from *coleos* (a sheath) and *pteron* (a wing). The beetles form one of the largest orders, with over twelve thousand species in America north of Mexico, belonging to some eighty families, only the most common of which will be mentioned. They have a complete metamorphosis, the larvæ being commonly called grubs, and the pupæ are usually found either in the ground

or in the foodstuff of the larvæ. Both larvæ and adults have biting mouth-parts, similar to those of the grasshopper, the structure varying with the food habits of the species.

The families of beetles are divided into several groups, based largely on the structure of the tarsi and antennæ, which aid the student in their identification. The order is primarily divided into the typical beetles (*Coleoptera genuina*), in which the head is normal, and the snout-beetles (*Rhynchophora*), in which the head is prolonged into a snout, or beak, at the tip of which are the biting mouth-parts.

The Typical Beetles (*Coleoptera genuina*)

Four principal sections of the families of typical beetles are distinguished by the number of segments in the tarsi.

I. Beetles with Five-jointed Tarsi (*Pentamera*)

The first section is distinguished by all of the tarsi being composed of five segments, and is divided into four tribes according to the structure of the antennæ.

The Carnivorous Beetles (Adephaga)

The carnivorous, or predacious, beetles include several families, all of which feed upon other insects and are therefore beneficial. The antennæ are threadlike, with distinct, cylindrical segments.

Fig. 190. A tiger-beetle (*Cicindela limbata*). (Hair line shows natural size)

(After Bruner)

The tiger-beetles (*Cicindelidae*). Along sandy paths, roadsides, railroad embankments, and in similar open, sunny spots, the tiger-beetles fly up and dart swiftly ahead as one approaches. They are swift runners and stalk their prey on foot. Most of our common species are either a brilliant, metallic green or a brownish-bronze, banded or spotted with yellow. The larvæ live in little burrows in the ground, the head appearing at the opening so that the eyes command the surroundings, and any unwary passing insect may be seized with the strong jaws. Toward the tip of the abdomen

is a decided hump, and surmounting it are strong, curved spines which serve as an anchor, so that a captured insect cannot drag the larva from its burrow. The voracity of these beetles makes the name "tiger-beetle" fitting, but unfortunately they are of little benefit to the farmer, as they do not frequent cultivated fields, and though they destroy many insects, but few of them are of any economic importance. The brilliant green species are favorites of collectors, and one must be something of a sportsman to secure many of them, so readily do they fly. Like many other active insects they may often be easily caught towards sundown.

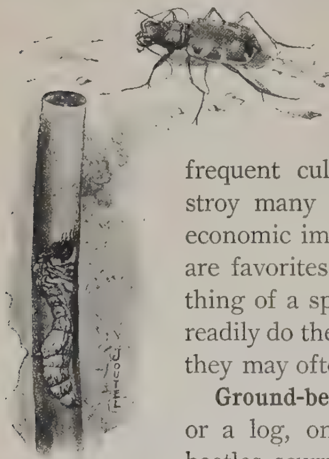

FIG. 191. A tiger-beetle and its larva in its burrow. (Natural size)

(After Linville and Kelly)

Ground-beetles. Upon turning over a stone or a log, one frequently sees small, flat, black beetles scurrying away, which belong to the family of ground-beetles (*Carabidae*). Their name is indicative of their habits, as their long legs fit them for chasing rapidly over the ground in pursuit of small insects, though some of them ascend trees in search of caterpillars. This is a large family, which has some twelve hundred species in this country, and as both larvæ and

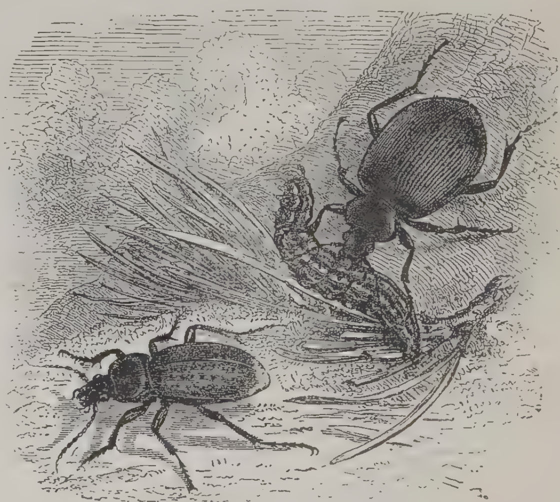

FIG. 192. A ground-beetle (*Calosoma* sp.) feeding on a cutworm; below, a species of *Carabus*

(After Brehm)

adults feed on many of our most noxious insects, ground-beetles must rank among the farmer's best friends. The larvæ live in the ground, or in places similar to those of the adults, and are also predacious. The larvæ are elongate, the body tapering slightly at either end, with the strong jaws projecting in front and two-bristly appendages at the tip of the abdomen. Our largest common species is the searcher (*Calosoma scrutator*), whose wing-covers are a beautiful green or violet, margined with reddish, and whose body is marked with blue, gold, green, and copper. It frequently ascends trees in search of caterpillars, and, with nearly related species, often does good work in destroying large numbers of them when they become overabundant. A European species of this genus has recently been imported into Massachusetts to prey upon the gypsy-moth caterpillars. A medium-sized species with yellowish-red head and thorax and bright blue wing-covers (*Lebia grandis*) (Fig. 195) has made a name for itself as an enemy of the eggs and larvæ of the Colorado potato-beetle. Our most common species are from one fourth to one half an inch long, either shining black or with greenish, bluish, or coppery reflections, and very frequently fly to lights in considerable numbers. Their larvæ feed on soft-bodied insects which go into the ground to pupate, such as the plum curculio and others, while the larger ones are among the most important enemies of cutworms and various caterpillars.

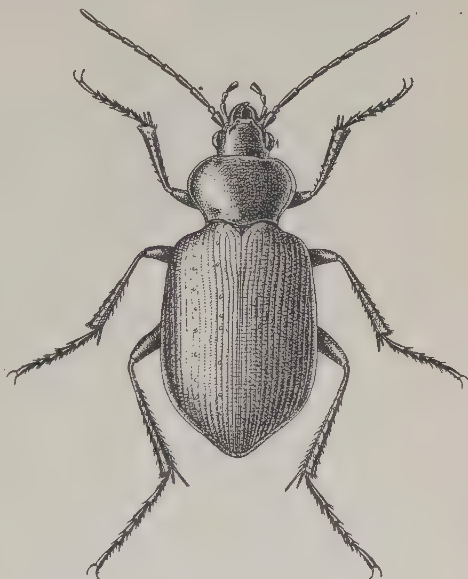

FIG. 193. European ground-beetle (*Calosoma sycophanta*) imported to prey on the gypsy and brown-tail moths

(After Howard, United States Department of Agriculture)

FIG. 194. A ground-beetle (*Calosoma calidum*). (Natural size)

The predacious diving-beetles (*Dytiscidae*) are to be found in any pond, where they may be seen suspended at the surface of the water with the tip of the abdomen thrust up so that air may be drawn in under the elytra, or diving here and there after their prey, which consists of any insects that they can overpower, small aquatic animals, and occasionally small fish. The largest species are about an inch long, while the commoner ones are one half or three fourths as large and are brownish-black, often marked with dull yellow. The hind legs are long, flattened, and fringed with hairs, forming admirable swimming organs. The larvæ are elongate, spindle-shaped grubs, with strong, ferocious-looking jaws, with which they grasp and suck out the juices of their prey, which has given them the name of water-tigers.

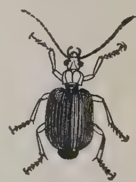

FIG. 195. *Lebia grandis*, an important enemy of the potato-beetle (Enlarged)

Whirligig-beetles. Every pool is the home of a school of the well-known whirligig-beetles (*Gyrinidae*), which chase each other over the surface, where they feed on small insects which fall into the water. They are usually much smaller than the last-named family, are oval in shape, much flattened, of a jet-black color, and

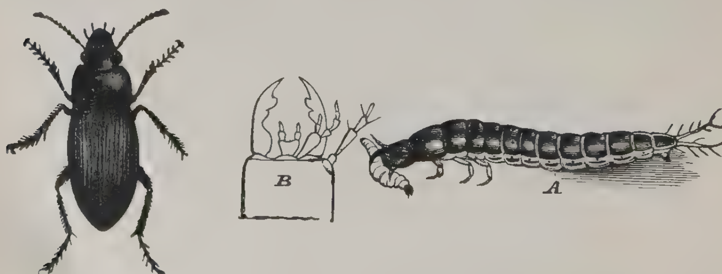

FIG. 196. A common ground-beetle (*Harpalus caliginosus*). (Enlarged) *A*, its larva; *B*, head of larva, showing mouth-parts. (After Riley)

are readily recognizable by the front margin of the head extending across the eyes so that there seems to be a pair of eyes on both the upper and the under surface.

The Club-Horned Beetles (*Clavicornia*)

The antennæ of the beetles of this tribe are either gradually or abruptly thickened toward the tip so as to form a club. The common families either live as scavengers or feed on stored products, but there is a large series of small families with the most varied habits, although not many include species of serious economic importance.

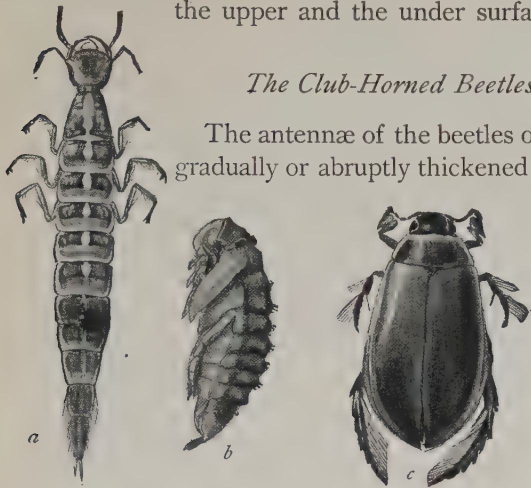

FIG. 197. A predacious diving-beetle (*Dytiscus* sp.). (Natural size)

a, larva, or "water-tiger"; *b*, pupa; *c*, adult. (After Kellogg)

The water-scavenger beetles (*Hydrophilidae*) closely resemble the predacious diving-beetles, but are more convex above and more flattened below, have more highly polished wing-covers, and have

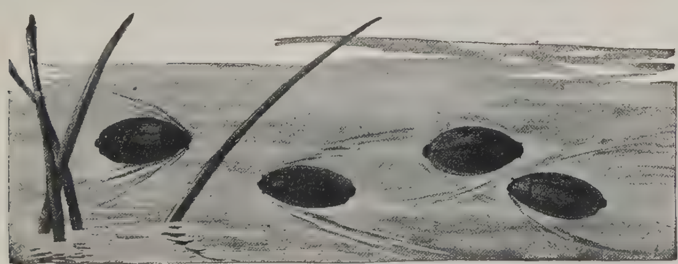

FIG. 198. Whirligig-beetles (*Gyrinidae*). (Natural size)
(After Linville and Kelly)

antennæ that are decidedly clubbed, though often concealed beneath the head. They feed on decaying animal and plant tissues, though they not uncommonly catch small insects, and the larvæ feed

entirely on insects, snails, tadpoles, etc. Both middle and hind legs are developed for swimming and are used alternately.

FIG. 199. Water-scavenger beetles (*Hydrophilus* sp.), larva, and peculiar egg mass on leaf
(After Brehm)

Carrion-beetles (*Silphidae*). Wherever a dead animal has been left exposed, the carrion- or burying-beetles may be found feeding upon it. The more common carrion-beetles of the genus *Silpha* are of a broad, oval shape, much flattened, with small heads, and feed beneath the carrion. The burying-beetles (*Necrophorus*) are much larger, from an inch to an inch and a half long, with thick, stout, rectangular bodies, and with large heads. The common species are blackish, marked with dull red. Their name

FIG. 200. A burying-beetle (*Necrophorus* sp.). (Slightly enlarged)
(After Linville and Kelly)

is derived from their habit of excavating beneath dead animals, which they gradually drop beneath the surface and then cover with soil. Both adults and larvæ feed on decomposing animals and are among the chief natural agents for their sanitary disposal, though some species are predacious and others feed on decaying fungi. The larvæ are black, flattened, with the segments sharply marked, and are found with the adults.

FIG. 201. A carrion-beetle (*Silpha noveboracensis*) and larva. (One and one half times natural size)

(After Kellogg)

The rove-beetles (*Staphylinidae*). The rove-beetles are readily recognized by the very short wing-covers, usually not over a third of the length of the abdomen. Most species are very small, but the more common ones are from half an inch to an inch long, with narrow, parallel-sided bodies. They run about swiftly and when disturbed curl up the abdomen as if to sting. The larger common species are found with the *Silphidae* feeding on carrion or decaying organic matter, being commonly found in dump heaps, while the smaller species feed on pollen, fungi, or small insects.

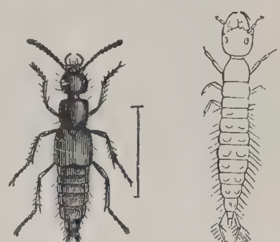

FIG. 202. A rove-beetle and its larva

Cucujidae. The saw-toothed grain-beetle (*Silvanus surinamensis*), which is one of our commonest grain pests, is a good example of the small family *Cucujidae*. It is a small, flat beetle, an eighth of an inch long, and readily distinguished from other small grain insects by the serrated edges of the thorax. It feeds also on all sorts of fruits, seeds, and dry pantry stores, as do the little whitish larvæ. The other common species are much-flattened beetles which live beneath bark and feed upon small insects and fungi. One of these (*Cucujus clavipes*) is a bright red, with eyes and antennæ black and tibiæ and tarsi dark, and is readily recognized by the thin body.

Larder-beetles. Every housewife knows that she must be on the lookout for the small carpet-beetle, often called the buffalo-moth (*Anthrenus scrophulariæ*), and for the larder-beetle (*Dermestes

lardarius), in stored meats or feathers. These are typical representatives of a small family, *Dermestidae*, of oval, plump beetles, the largest being about one third of an inch long. They are usually grayish, brownish, or blackish, marked with colors due to minute scales with which the body is covered. All of this family feed on

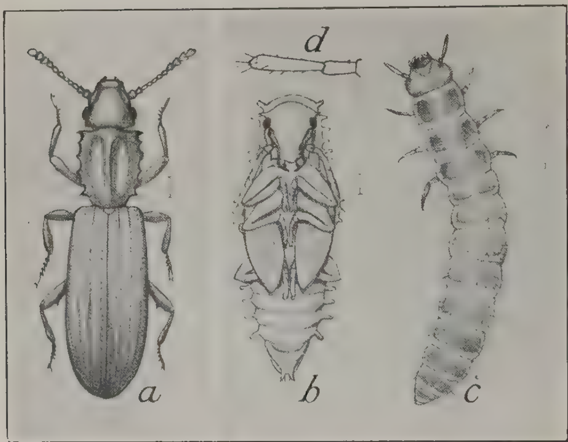

FIG. 203. The saw-toothed grain-beetle. (Much enlarged)
a, adult; *b*, pupa; *c*, larva. (After Chittenden, United States Department of Agriculture)

dried animal substances, and some of the smaller species are particularly noxious to the entomologist, as they are the worst pests which he has to combat in his collection cases.

The Saw-Horned Beetles (*Serricornia*)

The tribe of saw-horned beetles includes several families of quite different habits, which are very loosely related by all having serrated antennæ, the segments of the antennæ being prolonged inward so as to give the whole antenna a saw-toothed or serrate appearance.

Click-beetles. Every boy knows the long click-beetles, or snapping beetles (*Elateridae*), which, when placed on their backs, will flop up in the air with a decided click, or snap. They are flat, elongate beetles, the commoner forms being about three fourths of an inch long and of a dull brown color. The head is small and the posterior angles of the thorax are much prolonged, giving it

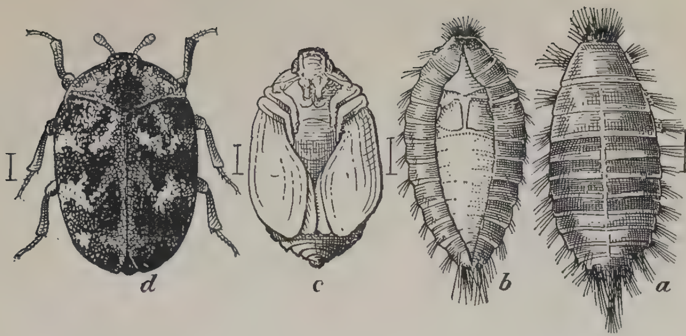

FIG. 204. The carpet-beetle, or buffalo-moth. (Enlarged)
a, larva; *b*, pupa in larval skin; *c*, pupa from below; *d*, adult. (After Riley)

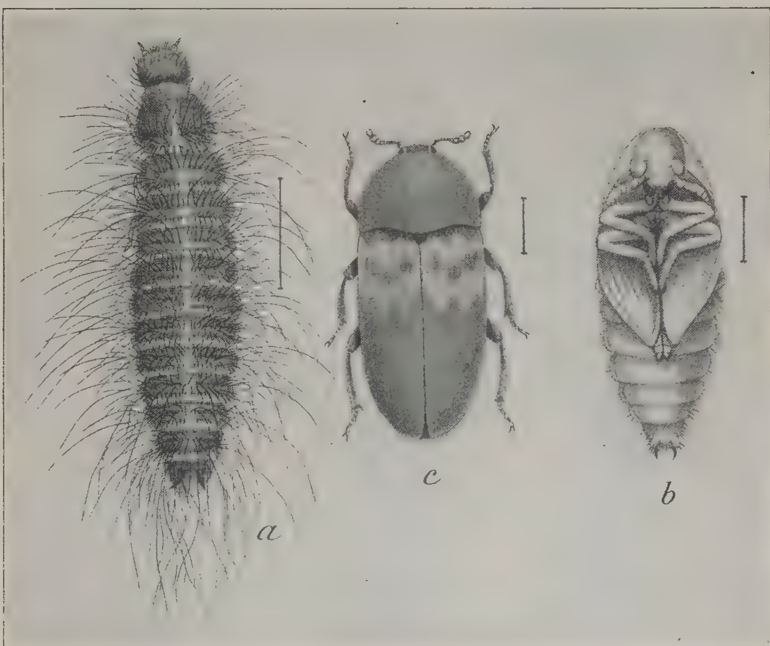

FIG. 205. The larder-beetle. (Enlarged)
a, larva; *b*, pupa; *c*, adult beetle. (After Howard, United States Department of Agriculture)

a characteristic shield shape. The larvæ are known as wire-worms and are among the worst pests of corn and small grains. Some wire-worms live under bark and in decaying wood, the adult of one of these being the common eyed elater (*Alaus oculatus*), a large species an inch and a half long, blackish, flecked with gray, with two large, velvet-black, white-rimmed eyespots on the thorax, which give it a very wise appearance.

Fig. 206. The eyed elater (*Alaus oculatus*.) (Slightly enlarged)

(After Linville and Kelly)

The metallic wood-borers (*Buprestidae*) have much the same general shape as the click-beetles, but the tips of the elytra are more pointed, the beetles are unable to spring, and their colors are metallic. The adults are medium-sized beetles, often found on flowers or bark, and do no harm as adults. The larvæ are flat, whitish grubs with small, brown heads

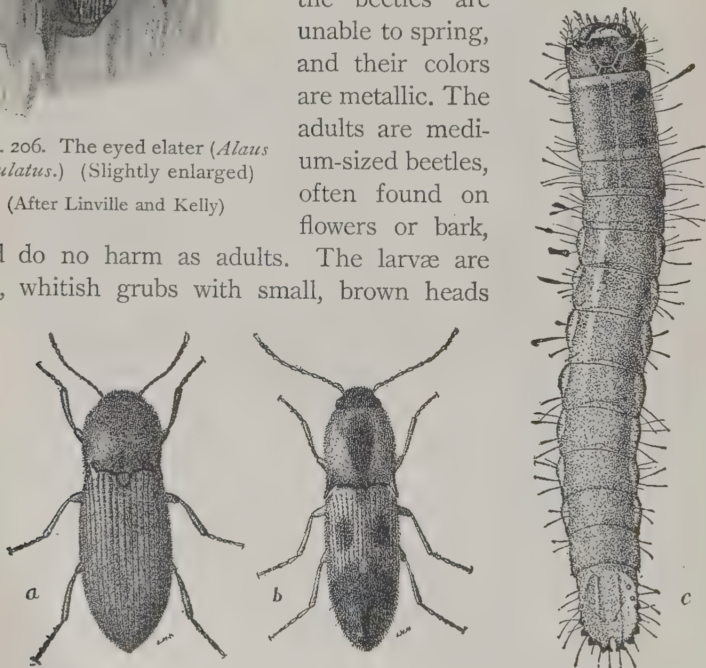

Fig. 207. *a*, beetle of wheat wire-worm (*Agriotes mancus*); *b*, beetle of *Drasterius elegans*; *c*, larva of same. (Much enlarged)

(After Forbes)

and with the prothorax greatly widened, giving them the name "flat-headed borers," which is also often applied to the family. They are to be found beneath bark, making irregular chambers in the sapwood and in the inside of the bark. Some feed only on dead or dying timber, while others, like the flat-headed apple-borer, attack healthy trees and often cause their destruction. One of the common smaller species is the red-necked blackberry-borer. It is a third of an inch long, with black wing-covers, dark bronze head, and coppery bronze prothorax. The larva bores in the sapwood of the raspberry and blackberry, causing a gall-like swelling, and when full grown bores into the pith, where it pupates.

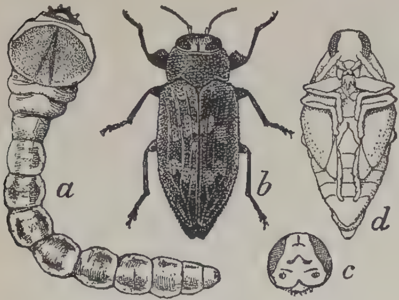

FIG. 208. Flat-headed apple-tree borer. (Twice natural size)

a, larva; *b*, beetle; *c*, head of male; *d*, pupa (After Chittenden, United States Department of Agriculture)

The fireflies (*Lampyridae*) which twinkle in the dusk of a warm summer evening are not really flies, but beetles, though their bodies and wing-covers are much softer in texture than those of most beetles. Most of the fireflies are medium-sized beetles, about half an inch long, of dull colors, with the prothorax expanded so as to cover the head. They are nocturnal in habit, the phosphorescent glow being produced by the underside of the terminal abdominal segments. Many of the females are wingless and are also phosphorescent, being known as glow-worms. The larvæ are predacious.

FIG. 209. A firefly beetle (*Photinus pyralis*)

a, larva; *b*, pupa in cell; *c*, adult. (After Riley)

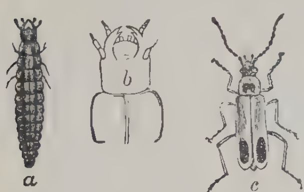

FIG. 210. Soldier-beetle (*Chauliognathus pennsylvanicus*)

a, larva; *b*, its head enlarged; *c*, adult. (After Riley)

Another group of this family, known as soldier-beetles, fly by day and are commonly found feeding on pollen, which they carry from flower to flower, thus aiding pollination. The common species are yellowish with black markings and with a prominent head. The larvæ are predacious and are among the important enemies of the larvæ of the codling moth and plum curculio.

The Leaf-Horned Beetles (*Lamellicornia*)

The tribe of leaf-horned beetles includes two families in which the terminal segments of the antennæ are greatly expanded and flattened, like plates or leaves, forming a club.

The stag-beetles (*Lucanidae*). There are some fifteen species of stag-beetles in this country, which receive their name from the

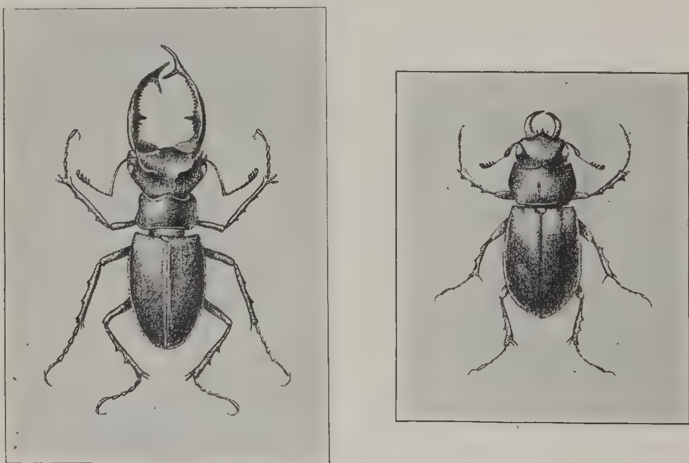

FIG. 211. Stag-beetles. (Natural size)
At the left, *Lucanus elephas*, male; at the right, *Lucanus dama*, male.

enormous jaws of some of the males, which are branched so as to have a fancied resemblance to the antlers of a stag. They are large brown or black beetles, from an inch to an inch and a half long, and the large mandibles have given them the name of "pinching-bugs." The beetles feed on sap and decaying wood, and the larvæ, which are much like white grubs, are found in decaying trunks and stumps. A shining black species, bearing a short horn

bent forward on the head, is frequently found beneath the bark of stumps and in rotting wood, and has been termed the horned passalus (*Passalus cornutus*).

FIG. 212. *Passalus cornutus*. (Slightly enlarged)

Scarabaeidae. With over five hundred species in this country, the Scarabaeidae form one of the largest and most important families of beetles. They are thick-bodied beetles of the May-beetle, or June-bug, type, strong but clumsy, and many have the anterior tibiæ broadly flattened for digging. They may be divided into two main groups, the scavengers and the leaf-chafers. The larvæ of all of the species are commonly called white grubs, for although they vary greatly in size and structure, they all have the same general appearance of the white grub, with its large yellow or brown head with strong mandibles, long legs, thick, whitish

FIG. 213. Scarab beetle (*Ateuchus variolosus*) rolling egg-balls of dung, and Egyptian sculptures of Sacred Scarab

(After Brehm)

body, curved, wrinkled, more or less clothed with hairs, and with the tip segment of the abdomen enlarged. Of the scavengers, the tumble-bugs are well known, as they are often seen rolling balls of manure along the roadside, which are finally buried and in which the eggs are laid. The fat grub feeds within this ball until ready to pupate. The famous sacred scarabæid was held in high veneration by the ancient Egyptians, who placed it in their tombs and carved it on sarcophagi, stones, and gems. With the first spring days one encounters swarms of little brown, black-spotted beetles which fill the air. They belong to numerous species of the genus *Aphodius*, the larvæ of which develop in manure and are often found in the dung of horses and cattle in pastures. Some of the scavengers make burrows in the soil under

FIG. 214. A dung-beetle (*Aphodius granarius* Linn.). (Greatly enlarged)

(After Forbes)

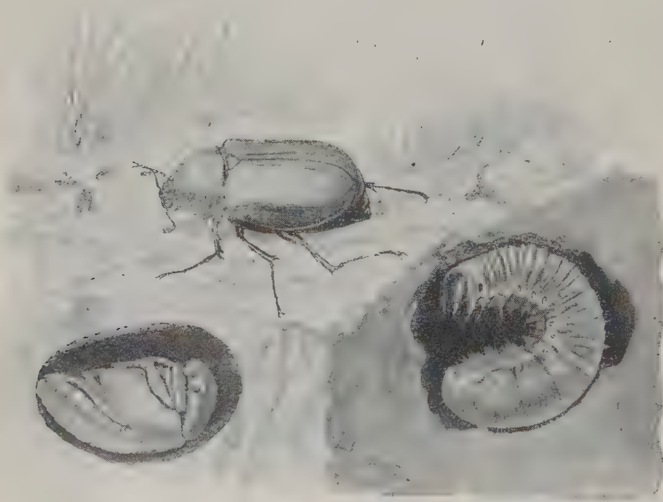

FIG. 215. May-beetle (*Lachnosterna* sp.), showing larva (or white grub), pupa, and adult. (Natural size)

(After Linville and Kelly)

droppings, which they carry in for food for the larvæ which live in the burrows, while others, known as skin-beetles, feed on dried or decomposing animal matter, frequenting the refuse of tanneries and eating the hoofs and hair of dead animals. Thus the scavengers may be considered as somewhat beneficial, but the leaf-chafers include many of our worst pests. The June-bugs, or May-beetles,

Fig. 216. The rose-chafer

a, adult; *b*, larva; *c*, *d*, mouth-parts of same; *e*, pupa; *f*, injured leaves and blossoms of grape, with beetles at work. *a*, *b*, *e*, much enlarged; *c*, *d*, more enlarged; *f*, slightly reduced. (After Marlatt, United States Department of Agriculture)

are among the best-known representatives of this group. They are stout, brown, or blackish beetles nearly an inch long, which fly in and buzz around the lights in early summer. There are some sixty species belonging to this genus (*Lachnosterna*), the larvæ of which are the typical white grubs which attack the roots of grass, corn, and garden crops. These beetles feed at night on various shade and fruit trees, ragging the foliage as if it had been torn. The rose-chafer is another well-known species, which destroys the

flowers and leaves of roses and grapes. It is a pale yellowish beetle, three eighths of an inch long, somewhat hairy, with long, pale red legs. All of the leaf-chafers have long, spiny legs, whose use they do not seem to have mastered, for they are ridiculously

FIG. 217. The rhinoceros beetle (*Dynastes tityus*). (Natural size)
(After Kellogg)

awkward in walking. The largest beetle of this country is the rhinoceros beetle (*Dynastes tityrus*), which is two and one half inches long, greenish-gray with black spots, and is named from the large horn on the head, which meets a median horn extending from the prothorax. It occurs in the South and West, and in the West Indies there is a similar species six inches long. Their larvæ live in the roots of decaying trees. Another series of species are known as flower-beetles, from their habit of feeding on pollen, which they carry from flower to flower. A common species of this sort is the yellowish-brown bumble flower-beetle (*Euphoria inda*). It is half an inch long, quite hairy, and flies from flower to flower with a loud buzzing like that of a bumble-bee. Occasionally these beetles assemble on ripening peaches or other soft fruits, or lap up the sap from a wounded tree. A bright-green species (*Allorhina nitida*), two thirds of an inch long, is very common in the South, where it is often called the green June-bug, and frequently attacks ripening fruits. The larvæ are white grubs which live in grasslands and often injure lawns.

FIG. 218. The bumble flower-beetle (*Euphoria inda*). (Twice natural size)
(After Chittenden, United States Department of Agriculture)

II. BEETLES WITH FOUR-JOINTED TARSI (*TETRAMERA*)

The tarsi of the families of this section are apparently composed of but four segments, the fourth being very small and closely joined to the last, or fifth, segment, and concealed by the third segment, which is deeply bilobed. This section is often called the *Phytophaga*, as all of the families attack vegetation.

FIG. 219. Tarsus of phytophagous beetle, showing indistinct fourth segment

(After Comstock, from Hunter)

The leaf-beetles (*Chrysomelidae*) are one of the largest and most injurious families, there being some six hundred species in this country, a large number of which injure cultivated crops, while those which normally feed on various weeds often change their food habits and become crop pests. The Colorado potato-beetle (*Leptinotarsa decemlineata*) is one of the best-known species, and is fairly typical of the family, except that it is much larger than the average. The little black, red-and-yellow-spotted asparagus-beetles which, with their dark grayish, sluglike larvæ, eat into young asparagus, are well known throughout the East, as are the twelve-spotted asparagus-beetles, which are red with twelve black spots.

FIG. 220. The common asparagus-beetle, — eggs, larva, and adult. (Much enlarged)

(After Britton)

From North Carolina and Ohio to Maine the elm leaf-beetle (*Galerucella luteola*) is the worst insect pest of elm foliage, both

FIG. 221. The Colorado potato-beetle. (Enlarged)

a, beetle; *b*, eggs; *c*, young larva; *d*, full-grown larva. (After Chittenden, United States Department of Agriculture)

adults and larvæ skeletonizing the leaves and so defoliating trees that, where injured annually, many are killed. The beetles are one fourth of an inch long, yellowish-brown, with black stripes at

the outer margin of the wings, and the full-grown larvæ are half an inch long, orange-yellow, with numerous black tubercles. The

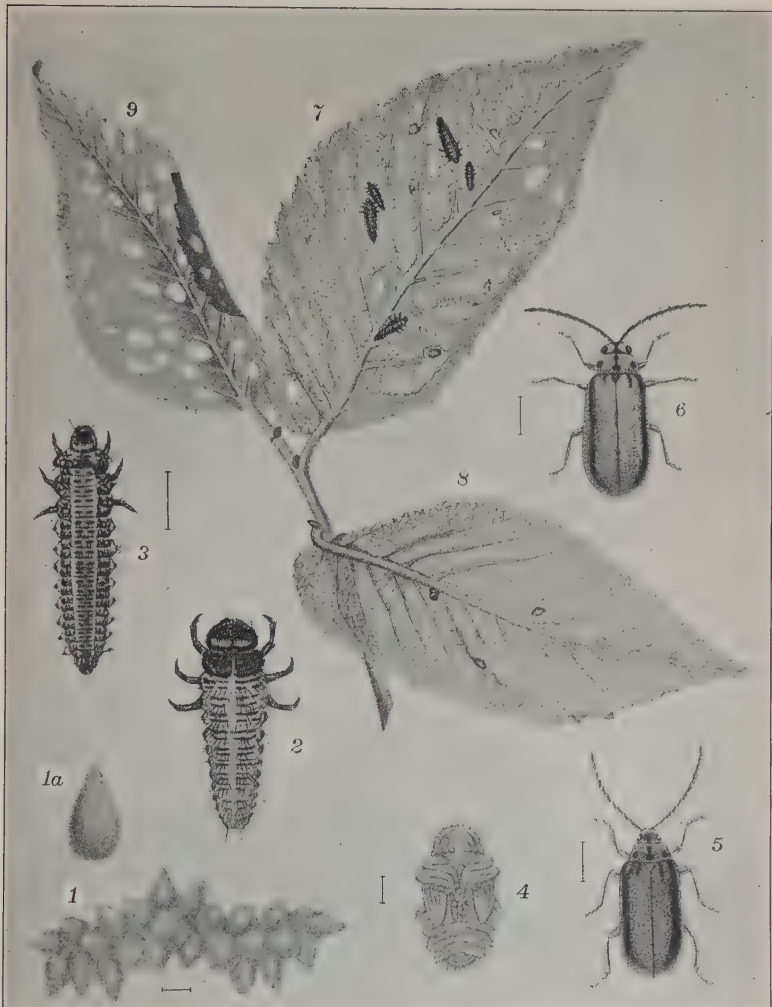

FIG. 222. The elm leaf-beetle

1, cluster of eggs; *1 a*, single egg; *2*, newly hatched larva; *3*, full-grown larva; *4*, pupa; *5*, overwintered beetle; *6*, newly transformed beetle; *7*, leaf showing work of grubs and a few holes eaten by beetles; *8*, leaf nearly skeletonized by larvæ; *9*, leaf showing holes eaten by beetles. (All enlarged except *7*, *8*, *9*, which are slightly reduced.) (After Felt)

FIG. 223. Striped cucumber-beetle

striped cucumber-beetle (*Diabrotica vittata*) is about the same size, bright yellow with black stripes, and is one of the worst pests of young cucumber and melon vines. The larvæ are long, slender whitish grubs which feed on the roots. The twelve-spotted Diabrotica is green with twelve black spots, with similar food habits in the adult stage, but in the South the larvæ do serious injury to the roots of corn, while the larva of another pale green species, known as the western corn rootworm, is one of the worst pests of corn in the northern Mississippi Valley. A large group of small species, with strong hind legs which enable them to give remarkable jumps, are known as flea-beetles. The potato flea-beetle (*Epitrix fuscula*) and nearly related species are commonly abundant on young potato and tomato plants, and on egg-plants, the leaves of which are riddled as if they had been hit with fine bird shot. The larvæ are small, slender white grubs, which feed on the roots of various weeds of the same botanical family, and are rarely seen. All the garden crops, as well as tobacco and corn, are attacked by one or more species of these flea-beetles. The larvæ of a few species of this family are leaf miners, the leaves of the locust being commonly affected by large, brown, blisterlike mines due

FIG. 224. *A*, potato flea-beetle; *B*, egg-plant flea-beetle. (Both greatly enlarged)

(After Chittenden, United States Department of Agriculture)

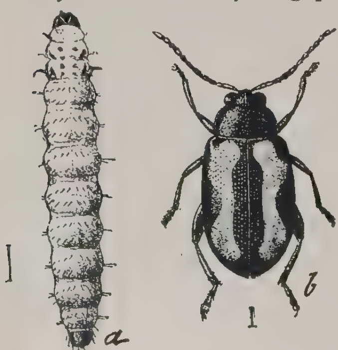

FIG. 225. Striped turnip flea-beetle (Greatly enlarged)

a, larva; *b*, adult. (From Riley, United States Department of Agriculture)

to the larvæ of the locust-beetle (*Odontota dorsalis*). On morning-glory and sweet-potato vines are found some striking little beetles,

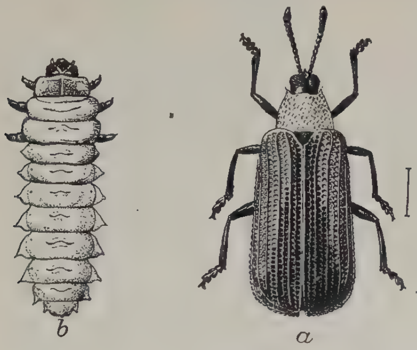

FIG. 226. The leaf-mining locust-beetle (*Odontota dorsalis*).
(Five times natural size)

a, beetle; *b*, larva; *c*, pupa. (After Chittenden, United States Department of Agriculture)

called tortoise-beetles, from their tortoiselike shape, several of which are of a brilliant gold or silver color. The larvæ feed on these

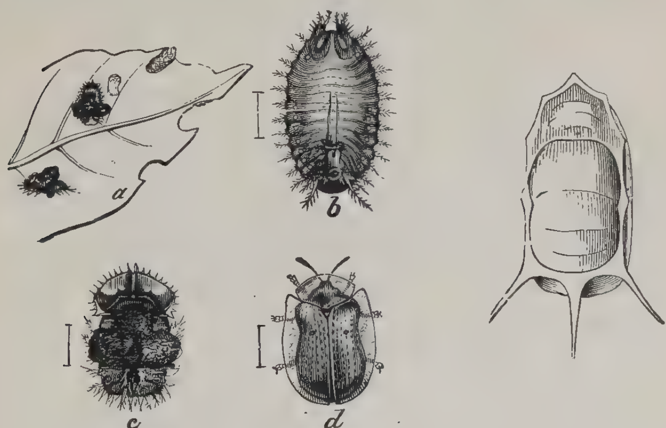

FIG. 227. The golden tortoise-beetle (*Coptocycla bicolor* Fab.); egg at right. (Enlarged)

a, *b*, larvæ; *c*, pupa; *d*, beetle. (After Riley)

plants, and are curious little creatures, carrying a mass of excrement over the back, which has given them the name "peddlers."

The pea-weevil family (*Bruchidae*) includes the small weevils which commonly infest peas, beans, and other seeds. They are of much the same general shape as some of the leaf-beetles, but the head is prolonged into a blunt snout, and the wing-covers are square at the tip, leaving the tip of the abdomen exposed. They are from one eighth to one fourth of an inch long, brownish or ashen gray in color, with whitish scales or hairs on the wing-covers, forming various markings. Both beetles and larvæ feed on seeds of leguminous plants, of which they are the most serious insect pests.

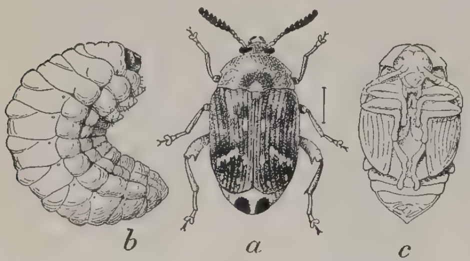

FIG. 228. The pea-weevil. (Enlarged)
a, adult beetle; *b*, larva; *c*, pupa. (After Chittenden, United States Department of Agriculture)

The long-horned beetles (*Cerambycidae*) are easily recognized by the long antennæ, which are rarely shorter than the body and often are twice as long. They are large, stout, cylindrical-bodied beetles, usually strikingly colored and patterned, attracting immediate attention. The larvæ are cylindrical white grubs which bore in the heartwood of trees and are termed round-headed borers, in contrast with the flattened forms of the *Buprestidae*. The family is a

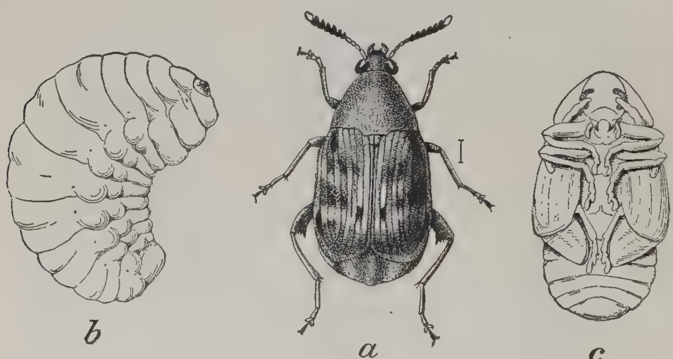

FIG. 229. The common bean-weevil. (All enlarged)
a, beetle; *b*, larva; *c*, pupa. (After Chittenden, United States Department of Agriculture)

FIG. 230. The round-headed apple-tree borer, — larvæ, adults, and exit hole. (Natural size)

(After Rumsey and Brooks)

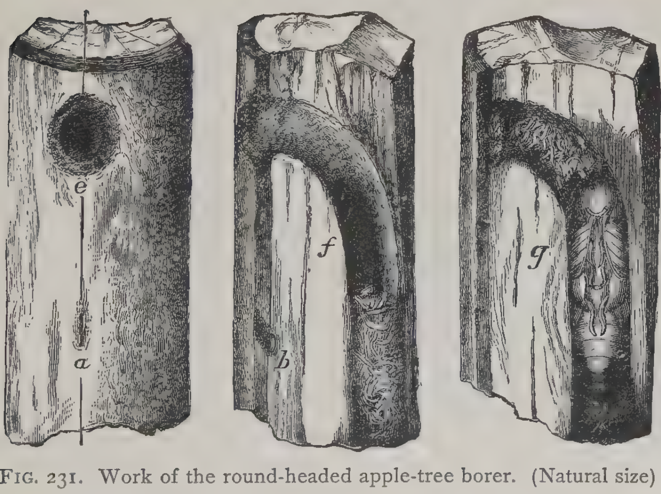

FIG. 231. Work of the round-headed apple-tree borer. (Natural size)

a, puncture in which egg is laid; *b*, same in section; *e*, hole from which beetle has emerged; *f*, same in section; *g*, pupa in its cell. (After Riley)

large one and includes many serious pests, such as the round-headed apple-tree borer and others with similar habits. Three common blackish species, brilliantly striped with yellow (Fig. 234), are known as locust-borer, hickory-borer, and sugar-maple-borer, after their respective food plants, which are frequently killed from the work of their larvæ. Among our largest beetles are the prionids, the larvæ of which infest the roots of various fruit and shade trees and herbaceous plants. The broad-necked prionus is from one to two inches long, pitchy black, with the thin margin of the prothorax toothed, as shown in Fig. 232. The oak-pruner is a slender, brown species, about three fourths of an inch long, which lays its eggs in the twigs of oak, maple, and various fruit trees. The larvæ hollow out the interior of the twigs which are broken off by the winds, and in these they pupate. One of our largest species is the common sawyer, a large gray beetle one and one fourth inches long, with very long antennæ, whose larvæ bore into the heart of felled pine and other softwood trees, making large holes half an inch in diameter. The raspberry cane-borer (*Oberea*

FIG. 232. The giant root-borer (*Prionus laticollis*)

(After Riley)

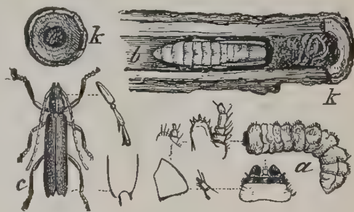

FIG. 233. The oak-pruner (*Elaphidion parallelum*)

a, larva; *b*, pupa in its burrow; *c*, beetle; *k*, *k*, cut ends of twig. (After Riley)

FIG. 234. The hickory-borer (*Cyllene pictus* Dru.). (Enlarged)

(After Webster)

bimaculata) is a black beetle half an inch long, with yellow prothorax bearing two black spots. Its larva mines raspberry and blackberry canes. The red milkweed-beetles (*Tetraopes tetraophthalmus*) are always common on the flowers of the milkweed, and the larva bore in the roots and stems.

III. BEETLES WITH THREE-JOINTED TARSI (*TRIMERA*)

The ladybird-beetles (*Coccinellidae*) form the only family of the section *Trimera*, in which the tarsi have but three segments, and

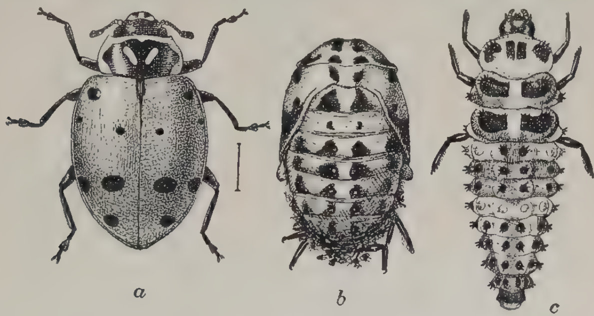

FIG. 235. The convergent ladybird-beetle (*Hippodamia convergens*)

a, adult; *b*, pupa; *c*, larva. (After Chittenden)

the head is usually concealed beneath the prothorax. Their small size (few being over one fourth of an inch long), their broad, oval, or hemispherical shape, and their characteristic markings, consisting of "polka-dot" black spots on a yellow or red background, or red or yellow spots on black, make them readily recognizable, though now and then certain of the leaf-beetles, which have a general resemblance, are mistaken for them. Nearly all of this

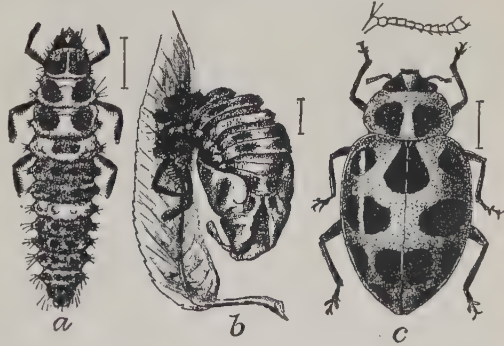

FIG. 236. The spotted ladybird-beetle (*Megilla maculata*)

a, larva; *b*, pupa; *c*, adult. (After Chittenden, United States Department of Agriculture)

family feed on plant-lice, scales, and other soft-bodied insects, both as adults and as larvæ, and may be found wherever their prey becomes abundant. In general the common yellow or red, black-spotted species feed on plant-lice, while the smaller black species, marked with red or yellowish spots, feed on scales. So common are the ladybirds among colonies of plant-lice that they are frequently mistaken as the parents of the aphides, and the misguided grower carefully picks them off and destroys them, thinking he is eliminating the cause of the aphid infestation, whereas he is really destroying nature's most efficient agents for its alleviation. The eggs are laid in little yellow masses on the leaves or bark whereever food is abundant. The larvæ are commonly about one fourth of an inch long, taper strongly at each end, have long legs, and are often marked with spiny processes. They run here and there in search of food, feed voraciously on any unlucky plant-lice or insects' eggs which fall in their path, and, when full grown, attach themselves to bark, leaves, or fences by the tip of the abdomen and there pupate, the cast larval skin often remaining over the pupa. The beetles hibernate over winter. The nine-spotted ladybird (*Coccinella 9-notata*) is one of the larger common yellow species, with nine black spots, and the little two-spotted ladybird (*Adalia bipunctata*) is smaller, slightly broader, and frequently associated with the former species. The twice-stabbed ladybird (*Chilocorus bivulnerus*) is black with a red spot on each wing-cover. Its spiny larva is black, and, with the adult, feeds upon scale

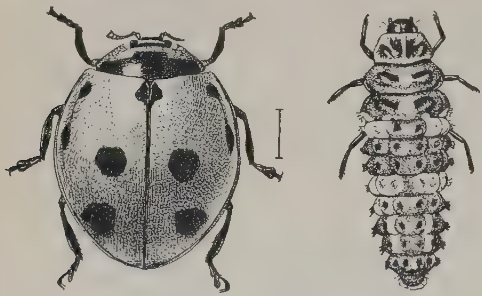

FIG. 237. The nine-spotted ladybird-beetle (*Coccinella novemnotata*), — adult and larva

(After Chittenden)

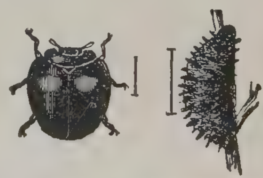

FIG. 238. The twice-stabbed ladybird-beetle (*Chilocorus bivulnerus* Muls.) and larva. (Enlarged)

(After Riley)

FIG. 239. Pupæ of the twice-stabbed ladybird-beetle, in cast larval skins

insects, often checking their increase noticeably. Recently a very similar species, the Asiatic ladybird, was imported from China to prey upon the San José scale, but has not become established in this country. Several very small, black species of the genus *Microweisea*, with their little black larvæ, are also among the most effective enemies of scale insects. One of the most remarkable cases of the utilization of a beneficial insect was the introduction into California of the Australian ladybird (*Novius cardinalis*), which in a few years was able to almost entirely subdue the cottony cushion-scale, which was destroying the orange trees. Unfortunately, there are some sinners among the ladybirds, for there are one or two large, hemispherical, black-spotted, yellow species of the genus *Epilachna*, which defoliate cucumbers, melons, and beans.

IV. BEETLES WITH DIFFERENT-JOINTED TARSI (*HETEROMERA*)

The section *Heteromera* is distinguished by having the front and middle feet with five tarsal segments, while the hind feet have but four; hence the name "different-jointed." A number of small, obscure families are included in this section, only two being of sufficient importance to warrant consideration.

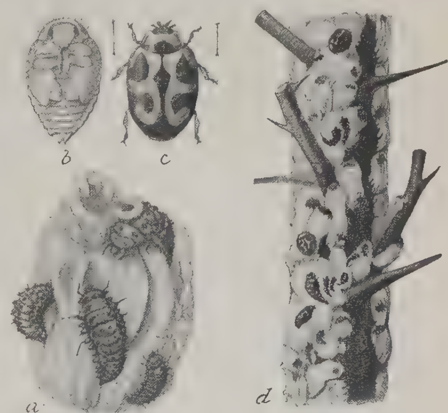

FIG. 240. Australian ladybird-beetle (*Novius cardinalis*), the enemy of the white scale. (Natural size)

a, ladybird larvæ feeding on adult female and egg sac; *b*, pupa; *c*, adult ladybird; *d*, orange twig, showing scales and ladybirds. (After Marlatt, United States Department of Agriculture)

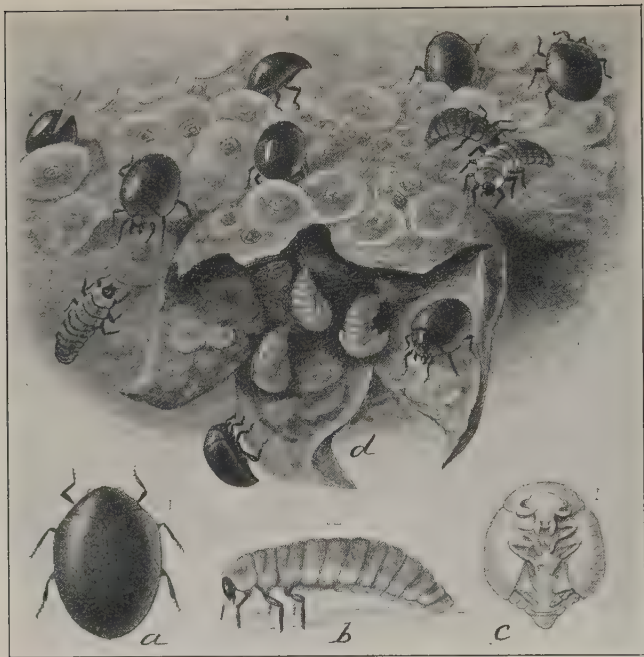

FIG. 241. *Microweisea misella*, a small black ladybird-beetle which feeds on scales. (All greatly enlarged)

a, beetle; *b*, larva; *c*, pupa; *d*, blossom end of pear, showing San José scales upon which the beetles and their larvæ are feeding, and pupæ in the calyx. (After Howard and Marlatt, United States Department of Agriculture)

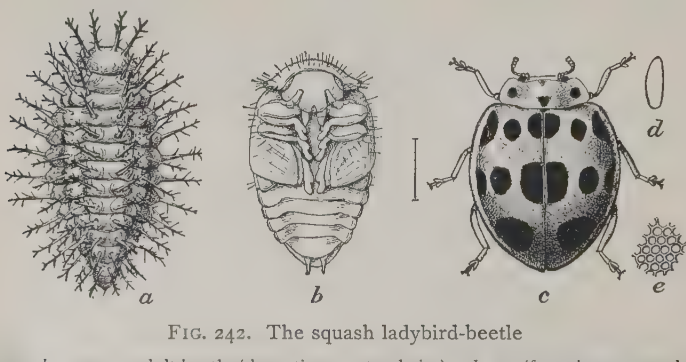

FIG. 242. The squash ladybird-beetle

a, larva; *b*, pupa; *c*, adult beetle (three times natural size); *d*, egg (four times natural size); *e*, surface of egg (highly magnified). (After Chittenden, United States Department of Agriculture)

The darkling beetles (*Tenebrionidae*) live mostly under bark and stones, are dull black, and have much the same general appearance as the ground beetles. They are much more abundant on the

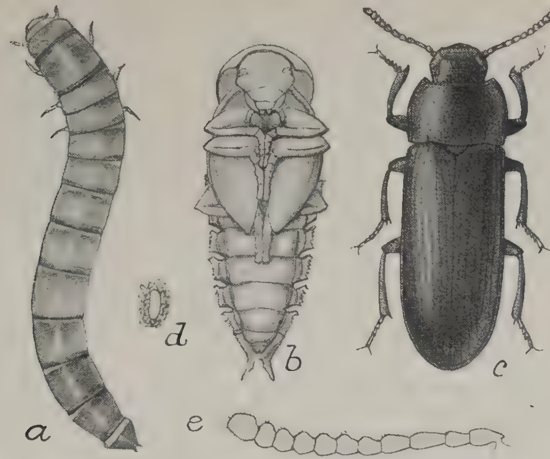

FIG. 243. The meal-worm (*Tenebrio molitor*)

a, larva; *b*, pupa; *c*, female beetle; *d*, egg with surrounding case; *e*, antenna. (All except *e* about twice natural size; *e*, greatly enlarged.) (After Chittenden, United States Department of Agriculture)

Pacific coast and in the Rockies, relatively few forms being found in the East. A common species of the typical genus is the meal-worm beetle (*Tenebrio molitor*) which infests grain-rooms, stores,

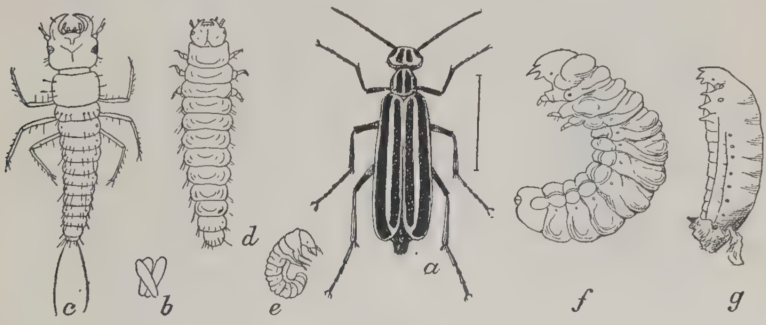

FIG. 244. The striped blister-beetle

a, female beetle; *b*, eggs; *c*, triungulin larva; *d*, second or carabid stage of larva; *e*, same as *f* doubled up as in pod; *f*, scarabæoid stage; *g*, coarctate larva. (All except *e* enlarged.) (After Riley and Chittenden, United States Department of Agriculture)

pantries, and wherever meal is stored. The larvæ are elongate, brown, and horny, very much resembling wire-worms, and are kept by bird fanciers for feeding song birds in winter. The beetle is from one half to three fourths of an inch long, dark brown, with square prothorax and ridged wing-covers.

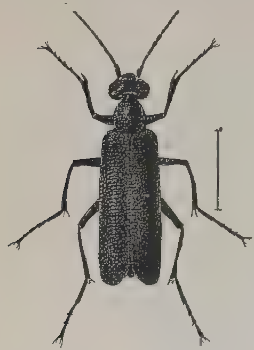

FIG. 245. The black blister-beetle. (Enlarged)

(After Chittenden, United States Department of Agriculture)

The blister-beetles (***Meloidae***) are so called because their juices cause a blistering of the human skin, and when dried and powdered they were formerly much used by physicians for blistering. They are soft-bodied beetles with the head prominent and attached to the thorax by a very distinct neck. The elytra are flexible and rounded posteriorly, so that usually they do not cover the tip of the abdomen, while in some forms the wing-covers are quite short and the wings are lacking. Our common species are about half an inch long, dull gray or blackish, often marked with yellow stripes, while others are of a brilliant metallic bronze, green, or blue. The adults often appear in immense swarms and ruin garden crops. The striped blister-beetle (*Epicauta vittata*) was a common pest of potatoes before the advent of the Colorado beetle, and is known as the "old-fashioned potato-bug." The larvæ have a very complicated metamorphosis, owing to their peculiar

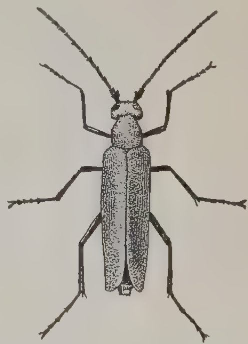

FIG. 246. The ash-gray blister-beetle. (Twice natural size)

(After Chittenden, United States Department of Agriculture)

FIG. 247. The white-pine weevil (*Pissodes strobi*). (Enlarged and natural size)

(After Hopkins, United States Department of Agriculture)

habits. Some of them are parasitic in the nests of bees, while the more common forms live on the eggs of grasshoppers, which they devour in large numbers, and are quite beneficial in spite of the bad habits which they later acquire as adults.

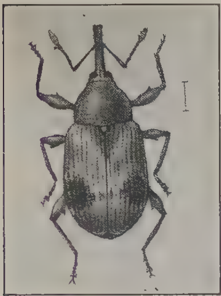

Fig. 248. The strawberry weevil. (Greatly enlarged)

(After Riley)

The Snout-Beetles (*Rhynchophora*)

In this suborder the head is prolonged into a long snout, giving the names "snout-beetles" "bill-bugs," "weevils," and "curculios" to many of the common forms. The body is strongly compact, usually well rounded above, and is more or less covered with scales. The antennæ arise from each side of the snout, are bent forward, or "elbowed," and end in a club. The larvæ are soft, footless, wrinkled, whitish grubs, with brown head, often thinly covered with short, bristly hair, and live mostly in fruits, nuts, or seeds, or under bark, though a few live on vegetation externally. All of the families attack plants and are therefore more or less injurious, some of our most troublesome pests being found in this series. Though there are common examples of several other families, only three families are sufficiently numerous to warrant mention.

Fig. 249. The cotton-boll weevil. (Enlarged)

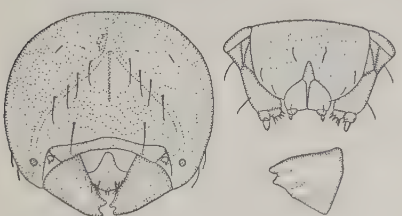

Fig. 250. Head and mouth-parts of the boll weevil larva

The curculios (*Curculionidae*) are the most typical as well as the largest family of the suborder,

with over six hundred species. With her long snout the female drills into fruits and stems and drops an egg in the bottom of the excavation. Here the larva feeds within the food plant, well protected against attack. In the northeastern states a brownish beetle, about one fourth of an inch long, with a white spot on each wing-cover, known as the white-pine weevil (*Pissodes strobi*), lays its eggs in the axis terminal of pines, which the larva tunnels out and kills, completely spoiling the shape of the tree. The plum curculio is the well-known little Turk which makes the crescent-shaped punctures on plums, peaches, cherries, and apples, and whose grubs feed within. A small blackish weevil, the strawberry weevil (*Anthonomus signatus*), lays its eggs in the strawberry buds, which it then cuts off, and the larvæ feed on the developing flowers, often causing serious loss. The cotton-boll weevil (*Anthonomus grandis*) is probably the most important species from an economic standpoint, causing a loss of over twenty-five million dollars annually. The most striking of all the weevils are the acorn and chestnut weevils, with snouts much longer than the body, enabling them to drill through the chestnut bur and deposit the egg within the nut, in which the larva develops. Almost all of our common nuts are attacked by some species of these weevils, which often are a serious nuisance.

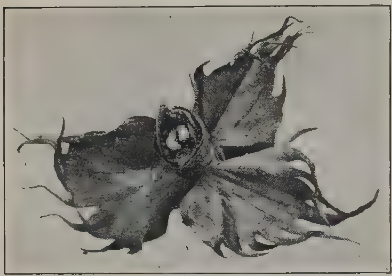

Fig. 251. Larva of the cotton-boll weevil in opened square. (Natural size)

Fig. 252. The chestnut weevil (*Balaninus proboscideus* Fab.). (Natural size)

Fig. 253. A corn bill-bug (*Sphenophorus ochreus*). (Twice natural size)

(After Webster)

The bill-bugs (***Calandridae***) are from one fourth to one half of an inch long, black, brown, or dark gray, with hard elytra, ridged and

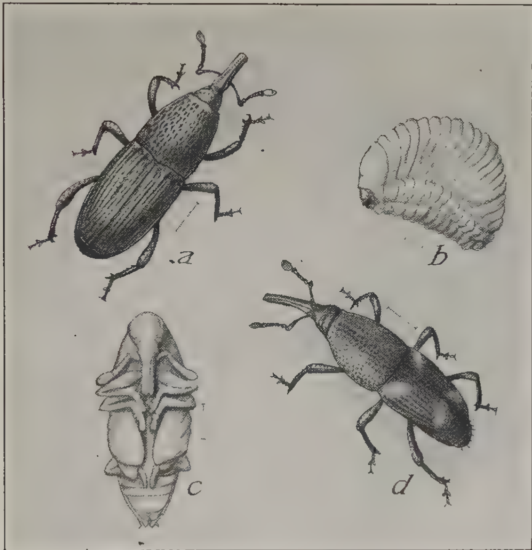

FIG. 254. The granary weevil (*Calandra granaria*). (Enlarged)

a, beetle; *b*, larva; *c*, pupa; *d*, the adult rice weevil (*Calandra oryzae*). (After Chittenden, United States Department of Agriculture)

sculptured. They attack corn, timothy, and other grasses, particularly the coarse swamp grasses and sedges. The fat white larvæ

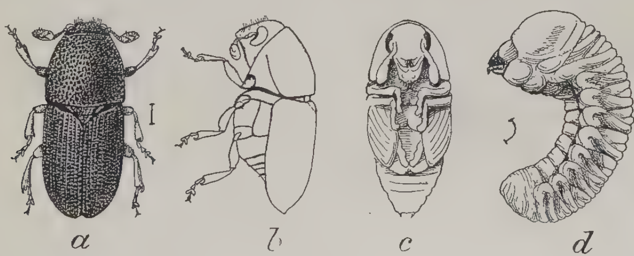

FIG. 255. The fruit-tree bark-beetle (*Scolytus rugulosus*)

a, adult; *b*, same in profile; *c*, pupa; *d*, larva (about ten times natural size). (After Chittenden, United States Department of Agriculture)

live in the crowns and stems of the plants. More important are the small granary and rice weevils (*Calandra granaria* and *oryzae*),

small, slender, brown weevils, one eighth of an inch long, which are the most abundant pests of granaries.

The engraver-beetles (*Scolytidae*), or bark-beetles, live on the inner bark and sapwood of forest and fruit trees, the larvæ of each brood tunneling out their little burrows in characteristic patterns, giving them the name of "engravers." They are small brown or blackish beetles, often microscopic, rarely over one eighth and never over one fourth of an inch long, and with the head very slightly produced, so that they are not readily recognized as snout-beetles. They have stout, cylindrical bodies, obliquely or squarely truncate at the tip. The larvæ are little white grubs, with brown heads and strong jaws, which riddle the inner bark of the food plant and pupate in the burrows. When the adults emerge, they make numerous small holes through the bark, which habit has given them the name of "shot-hole borers." This family includes the most destructive of all our forest insects, the losses due to them being estimated at over one hundred million dollars per annum. Almost every tree has species which commonly attack it in different sections of the country, some infesting only sick or dead timber, while others attack the healthy trees and sweep them off over large areas, the trees dying and giving rise to forest fires. The fruit-tree bark-beetle (*Scolytus rugulosus*) is a well-known example, infesting our common fruit trees.

FIG. 256. Typical work of a scolytid, the fruit-tree bark-beetle, showing the main galleries, the side or larval galleries, and the pupal cells. (Slightly enlarged)

(After Ratzeburg)

Synopsis of Families of Beetles

Suborder *Typical beetles* (*Coleoptera genuina*)
- Section 1. With five-jointed tarsi (*Pentamera*)
  - Tribe 1. Carnivorous beetles (*Adephaga*)
    - Tiger-beetles (*Cicindelidae*)
    - Ground-beetles (*Carabidae*)
    - Predacious diving-beetles (*Dytiscidae*)
    - Whirligig-beetles (*Gyrinidae*)
  - Tribe 2. The club-horned beetles (*Clavicornia*)
    - Water-scavenger beetles (*Hydrophilidae*)
    - Carrion-beetles (*Silphidae*)
    - Rove-beetles (*Staphylinidae*)
    - Cucujid-beetles (*Cucujidae*)
    - Dermestid-beetles (*Dermestidae*)
  - Tribe 3. The saw-horned beetles (*Serricornia*)
    - Click-beetles (*Elateridae*)
    - Metallic wood-borers (*Buprestidae*)
    - Fireflies (*Lampyridae*)
  - Tribe 4. The leaf-horned beetles (*Lamellicornia*)
    - Stag-beetles (*Lucanidae*)
    - Scarabæid beetles (*Scarabaeidae*)
- Section 2. With four-jointed tarsi (*Tetramera*)
  - Leaf-beetles (*Chrysomelidae*)
  - Pea-weevils (*Bruchidae*)
  - Long-horned beetles (*Cerambycidae*)
- Section 3. With three-jointed tarsi (*Trimera*)
  - Ladybird-beetles (*Coccinellidae*)
- Section 4. With different-jointed tarsi (*Heteromera*)
  - Darkling-beetles (*Tenebrionidae*)
  - Blister-beetles (*Meloidae*)

Suborder *Snout-beetles* (*Rhynchophora*)
- The curculios (*Curculionidae*)
- The bill-bugs (*Calandridae*)
- The engraver-beetles, or bark-beetles (*Scolytidae*)

CHAPTER XIII

THE BUTTERFLIES AND MOTHS (*LEPIDOPTERA*)

Characteristics. Insects with four wings, which are membranous and covered with overlapping scales; mouth-parts, suctorial; metamorphosis, complete.

If the wing of a butterfly or a moth is rubbed, the color is quickly removed as a sort of powder, leaving the transparent membranous wing. If this powder is examined with a microscope, it will be seen to be composed of small, finely ridged scales, which are arranged on the wings in overlapping rows and give it the characteristic color pattern. Thus we get the name of the order, from *lepis* (a scale) and *pteron* (a wing). These scales strengthen the wings and are also found on the body and on other appendages. The mouth-parts of the adults consist of a long, tubelike proboscis, which is coiled under the head when not in use, looking, in some of the larger moths, much like a watch spring. It is composed of the two maxillæ, the inner faces of which are grooved and locked together so as to form a tube, through which the nectar of flowers is sucked. The mandibles are entirely wanting. The two brushlike organs on each side of the proboscis are the labial palpi, the balance of the labium being poorly developed.

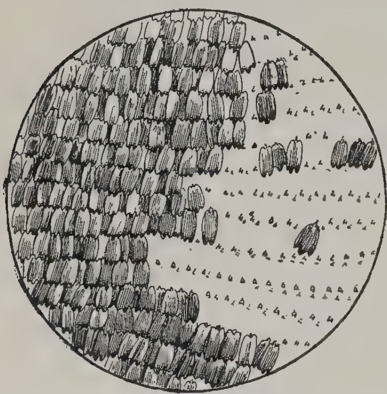

FIG. 257. Portion of wing of monarch butterfly, with some scales removed to show insertion-pits and their regular arrangement. (Greatly magnified)

(After Kellogg)

The larvæ of butterflies and moths are known as caterpillars. They are quite variable in shape, but our common forms are readily recognizable as belonging to this order. They are usually cylindrical,

with a well-developed head bearing biting mouth-parts and small ocelli on either side. The thorax bears three pairs of jointed legs, which terminate in a single claw, and the back of the prothorax forms a hard shield, the pronotum. The abdominal segments are very similar and bear from one to five pairs of short, fleshy, unsegmented false legs, or prolegs, which terminate in a circle of small hooks, one pair of which is always borne by the anal segment.

FIG. 258. Luna moth, showing pectinate, or feathered, form of moth antennæ

(After S. J. Hunter)

The caterpillars of many moths pupate in little cells, which they hollow out in the ground, but most of them spin silken cocoons, within which they pupate. Some are thin, flimsy affairs, while others, like those of the silkworm, contain a large amount of silk and are very firmly built, forming a warm home for the hibernating pupæ. Butterfly larvæ spin no cocoons, and the pupæ, or chrysalids, hang pendent from the food plant or some near-by object, to which they are sometimes lashed by a strand of silk around the body.

FIG. 259. A skipper (*Eudamus bathyllus*), showing recurved tips of antennæ

(After S. J. Hunter)

The order is one of the largest, including over sixty-six hundred species in this country, and contains many of our most serious pests, while very few of its members are beneficial. The families are largely distinguished by the wing venation, which is difficult to see, so that it is exceedingly hard to arrange them in any natural and easily

recognizable groups. The caterpillars of the different families may be recognized, to a certain extent, by their habits and general appearance. The *butterflies* and *moths* form two main divisions of the order, which are readily distinguished.

Butterflies

The butterflies are day fliers, and when at rest the wings are held in a vertical position over the back. The antennæ are threadlike and are distinctly enlarged at the tip.

The butterflies are much less numerous than the moths, both in families and in species, and include relatively few species of any considerable economic importance. Two main groups of butterflies are recognized, — the skippers (*Hesperina*) and the true butterflies (*Papilionina*).

Fig. 260. Hop-merchant butterfly, showing form of knobbed antennæ of butterflies

(Photograph by Fiske)

Skippers

The skippers are so called from their peculiar habit of darting suddenly from place to place. The wings are held vertically over the back when at rest, though often the hind-wings are held horizontally. The antennæ are enlarged at the tip, which usually forms a more or less recurved hook. They have stout bodies, which resemble moths more than butterflies. Some are blackish or dark, somber brown, often flecked with grayish or white, while others are tawny yellow with a blackish discal patch. The latter usually have the fore-wings much more pointed, and have thick bodies. The larvæ of our common forms have a characteristic appearance (Fig. 261), with large heads and strongly constricted necks. They feed on foliage, usually concealing themselves within a folded leaf, which is tied together with silk and within which they spin a loose cocoon

of silk before pupating. Very few of this group are of any economic importance, though one larva occasionally attacks the calla lily,

FIG. 261. The tityrus skipper (*Epargyreus tityrus*), — adult, larva, and leaf-cocoon. (Natural size)

(After Linville and Kelly)

and another sometimes injures corn in the Gulf States, perforating the leaves with numerous holes before they unfold. The skippers may be considered as intermediate between the moths and the true butterflies.

FIG. 262. The manataaqua skipper (*Pamphila manataaqua*), male. (Natural size)

(After Fiske)

TRUE BUTTERFLIES

The true butterflies include four well-defined families.

The swallowtails (*Papilionidae*) include our common black-and-yellow species, which have the hind-wings prolonged into characteristic tails. The only species of any economic importance is the celery, or parsley, caterpillar (*Papilio polyxenes*). The adult is our best-known swallowtail, jet-black with the outer edge of the wings marked with two rows of yellow spots, and a peculiar eyespot on

FIG. 263. The black swallowtail butterfly (*Papilio polyxenes*). (Slightly reduced)
a, egg; *b*, caterpillar; *c*, front view of head with osmateria protruded; *d*, chrysalis; *e*, *f*, adult. (After Webster)

the inner margin of each hind-wing. Between the rows of yellow spots on the hind-wings are bluish scales, which are particularly

FIG. 264. The blue swallowtail butterfly (*Laertias philenor*). (Reduced one fifth)

(Photograph by Fiske)

prominent in the females. The caterpillar is green, banded with black and spotted with yellow, and feeds on celery, parsley, parsnips, and nearly related plants. Like other caterpillars of this

FIG. 265. Caterpillar of the troilus butterfly (*Papilio troilus*)

(Photograph by Weed)

FIG. 266. The tiger swallowtail butterfly (*Papilio glaucus turnus*). (Reduced)

(Photograph by Weed)

FIG. 267. Three common pierid butterflies

a, native cabbage butterfly (*Pontia napi oleracea*), male; *b*, imported cabbage butterfly (*Pontia rapae*), female; *c*, the common sulphur butterfly (*Eurymus philodice*), female. (Photograph by Fiske)

family it has a pair of peculiar, orange-colored, membranous horns, which are protruded from between the segments close to the head and which give off quite a disagreeable odor. Evidently these are defensive organs, for they appear only when the caterpillar is disturbed. This family includes our largest and most brilliant butterflies. The spring and summer broods of some species are so differently colored that they might be taken for distinct species.

Pieridae. The family *Pieridae* includes the yellow butterflies (sometimes called puddle butterflies, from their habit of swarming around puddles) and the common white cabbage butterfly, which is almost the only form of economic importance in the family. The larvæ are slender green caterpillars, clothed with short, fine hairs, and are often finely striped, resembling the cabbage worms. The larvæ of the common clouded sulphur (*Eurymus philodice*) feed on clovers and leguminous plants, but are rarely numerous enough to be injurious.

FIG. 268. The common blue butterfly (*Lycaena pseudargiolus* Boisd.), underside of female

(After Fiske)

The gossamer-winged butterflies (*Lycaenidae*), so called on account of their delicate structure, include the little blue and copper-colored

FIG. 269. The bronze copper butterfly (*Chrysophanus thoe* Boisd.), female

(After Fiske)

butterflies which flit along the roadsides in spring. Others are blackish or bluish above, often with two or more fine, threadlike tails extending from the hind-wings, and are marked with fine, hairlike streaks on the under-surface, which has given them the name of "hair streaks." The larvæ are quite different from other caterpillars, being flat, elliptical in outline (with the head retracted), and quite sluglike in appearance. Very few of them are ever injurious, the worst offender being the cotton-square borer (*Uranotes mellinus*), which bores into cotton squares and occasionally attacks beans and cowpeas by eating into the pods.

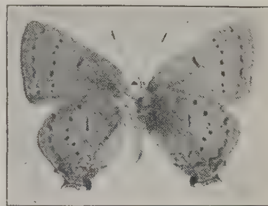

FIG. 270. The acadian hair-streak (*Thecla acadica* Edw.), underside of female

(Photograph by Fiske)

The four-footed butterflies (*Nymphalidae*) include most of our common larger forms, and are so called on account of the great reduction of the fore-legs; this makes them of no service in walking, and the legs are folded on the breast. The common monarch, or milkweed, butterfly (*Anosia plexippus*), whose green, black-ringed caterpillars feed upon the foliage of the milkweed, is a good example of the family. The spiny elm caterpillar, already described (see p. 63), also belongs here. The dark, reddish-brown butterflies of the hop merchant (*Polygonia comma*) are of interest, for when they fold their ragged-edged wings and alight

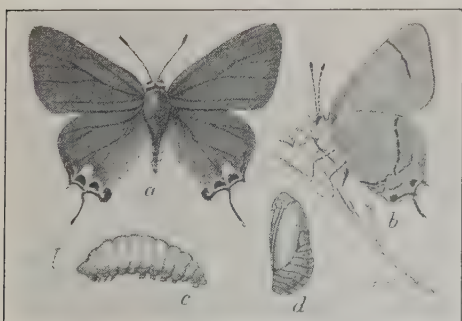

FIG. 271. The cotton square-borer (*Uranotes mellinus*). (All somewhat enlarged)

a, dorsal view of butterfly; *b*, butterfly with wings closed; *c*, larva (side view); *d*, pupa. (After Howard, United States Department of Agriculture)

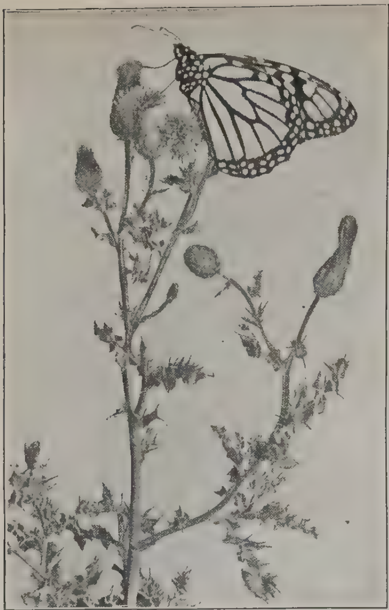

FIG. 272. The monarch butterfly (*Anosia plexippus*) on thistle. (Reduced)

(Photograph by Weed)

FIG. 273. The viceroy butterfly (*Basilarchia archippus*) and its chrysalis. (Reduced)

(Photograph by Weed)

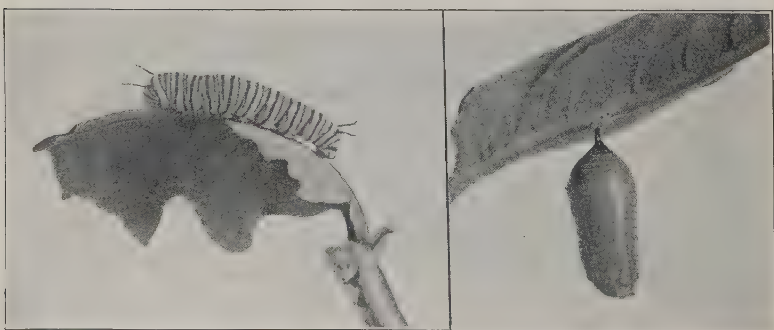

FIG. 274. Caterpillar and chrysalis of the monarch butterfly

(Photograph by Weed)

FIG. 275. Caterpillar of the viceroy butterfly. (Reduced)

(Photograph by Weed)

FIG. 276. The myrina butterfly (*Argynnis myrina* Cramer), male

(After Fiske)

FIG. 277. Harris's butterfly (*Melitaea harrisii* Scud.), undersurface, male

(Photograph by Fiske)

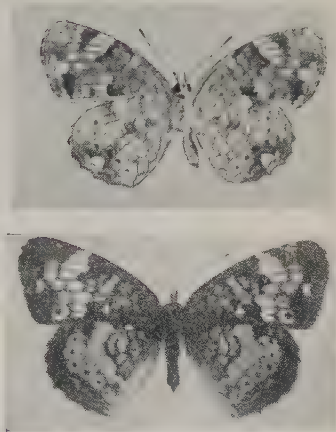

FIG. 278. The tharos butterfly (*Phyciodes tharos* Dru.), female, upper and under surfaces

(After Fiske)

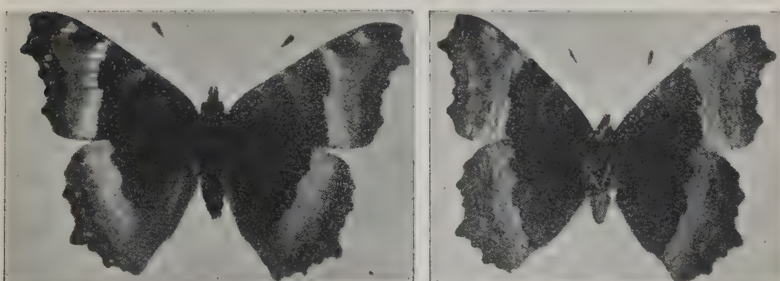

FIG. 279. The American tortoise butterfly (*Vanessa milberti* Godart), upper and under surfaces

(After Fiske)

among dead leaves, as they frequently do when pursued in woodland, the underwings so closely resemble the leaves as to make them quite indistinguishable. A bright, silvery comma is seen on the underside of each hind-wing, which gives the specific name. The larvæ are reddish or yellowish, with black head and black-branched spines; they feed on elm and nettles, though they are better known as pests of the hop-vine.

FIG. 280. Hunter's butterfly (*Pyrameis huntera* Fab.), male

(After Fiske)

The dull, grayish-brown butterflies, with numerous eyespots on the borders of their wings, which flit through our woodlands like changing shadows, are known as meadow-browns, or satyrs, and also belong to this large family. The larvæ of the more common species feed on grass, and may be recognized by the caudal segment being bifurcated.

The fritillaries, or *argynnids*, are another group of common butterflies included in this family. They are usually of medium size, of a golden-brown color, marked with rows of black spots above and with bright, silvery spots on the under-surface. There are several species which are very difficult to distinguish, and whose caterpillars feed on violets. One of the smaller species, very similar to the larger forms, is illustrated in Fig. 276.

FIG. 281. Hunter's butterfly at rest, showing underwing and chrysalis

(Photograph by Weed)

Moths

The moths fly by night, are readily attracted to lights, and are often called millers. When at rest the wings are folded upon or around the abdomen. The antennæ are thread-like or feathered, but are never enlarged at the tip.

Fig. 282. The white-banded purple butterfly (*Limenitis arthemis* Dru.), male

(After Fiske)

In striking contrast to the butterflies, most of our moths are little in evidence, but almost all of their caterpillars are injurious and require incessant fighting to control them.

No attempt will be made to indicate the natural relationships of the families, which will be grouped and described in such a way as to best aid in their recognition. Several of the more uncommon families have been purposely omitted from the discussion.

Fig. 283. The canthus butterfly or eyed brown (*Neonympha canthus* Boisd. and Lec.), undersurface

(After Fiske)

Three large, nearly related families of small moths are commonly grouped together as Microlepidoptera, on account of their relatively small size in contrast to the remaining families. The larger moths and the butterflies are termed Macrolepidoptera. This grouping together of the larger and smaller moths is a classification for the convenience of the collector and is not based on any specific difference of structure.

MICROLEPIDOPTERA

The tineids (*Tineidae*) are our smallest moths and may be distinguished by the long, narrow wings having a broad fringe of hair, particularly on the hind-wings, which are often very

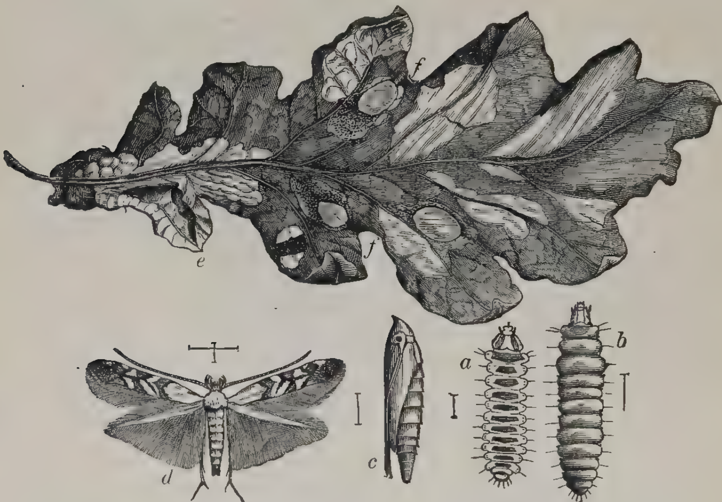

FIG. 284. A tineid leaf-miner of the oak (*Lithocolletis hamadryadella*)

a, *b*, larva, flat and round forms; *c*, pupa; *d*, moth; *e*, oak leaf showing mines, with cocoons at *f*, *f*. (After Comstock)

narrow, with a fringe several times as broad. Many of the larvæ are leaf-miners, feeding between the surfaces of leaves, in which they tunnel out mines whose shape is characteristic of the species; some are linear, others serpentine, some are trumpet-shaped, while others are irregular blotches. These little larvæ are usually white, and are very much flattened, with small, wedge-shaped heads,

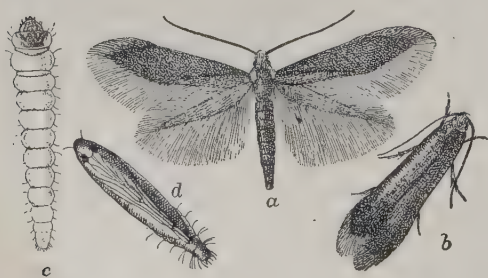

FIG. 285. The apple leaf-miner. (Greatly enlarged)

a, moth; *b*, moth at rest; *c*, larva; *d*, pupa. (After Quaintance, United States Department of Agriculture)

with only rudiments of legs, and with the abdomen constricted between the segments. Many of them hibernate in the fallen

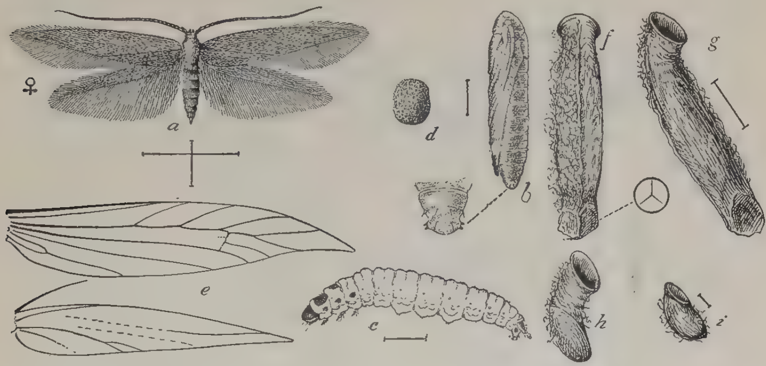

FIG. 286. The cigar-case bearer. (Much enlarged)

a, female moth; *b*, side view of pupa; *c*, larva; *d*, egg; *e*, wing venation; *f*, upper view of cigar-shaped case with three-lobed opening at tip; *g*, side view of same; *h*, the case as it appears in the spring; *i*, the fall and winter case. (After Hammar, United States Department of Agriculture)

leaves, in which they pupate and transform the next summer. A well-known example is the apple-leaf trumpet miner (*Tischeria malifoliella*), whose brown, trumpet-shaped mines are common in apple leaves and often cause considerable damage. Some of the caterpillars of this family make little cases of silk, in which they reside and which are carried over the abdomen as they feed on the foliage, much like the shell of a snail. Common examples are the pistol-case bearer and the cigar-case bearer, which are common on apple foliage and are so named

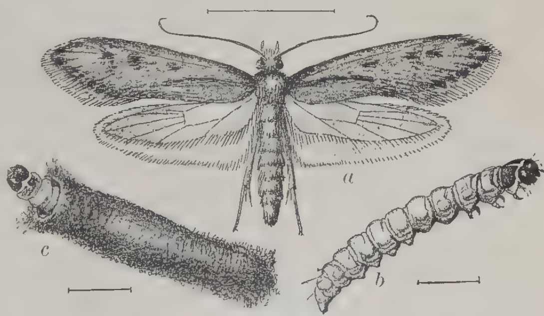

FIG. 287. The case-making clothes moth (*Tinea pellionella*). (Enlarged)

a, adult; *b*, larva; *c*, larva in case. (After Riley)

from the shapes of the cases. Nearly related to them are the little clothes moths, the plague of every housekeeper, which feed on woolens, furs, etc. There are several species: one makes a case of bits of food fastened together with silk, another builds a tube, and a third feeds unprotected. The more common forms are of a brown color and may be distinguished from other small moths which frequent the house by the broad fringe to the wings already mentioned. Another member of this family which is a serious pest of stored corn in the South is the angoumois grain-moth (*Gelechia cerealella*), whose larvæ live in the kernels of corn and annually destroy millions of dollars' worth.

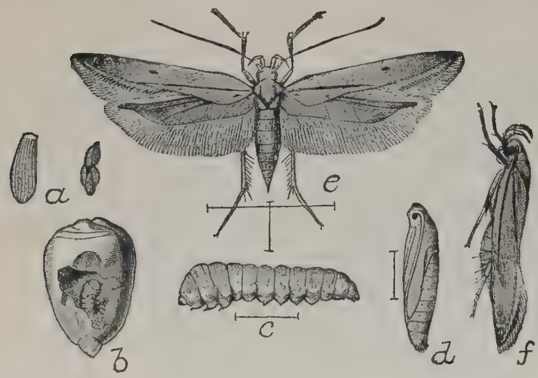

FIG. 288. The angoumois grain-moth (*Sitotroga cerealella* Ol.). (Enlarged)

a, eggs; *b*, larva at work; *c*, larva; *d*, pupa; *e*, *f*, moth. (After Chittenden, United States Department of Agriculture)

The leaf-rollers (*Tortricidae*). Here and there on various shrubs and plants will be found leaves which have been rolled up and fastened together with silk by a little caterpillar living within. Most of this is done by the leaf-rollers, which are the most characteristic of the family *Tortricidae*, though by no means all leaf-rollers belong to this group. The oblique-banded leaf-roller (*Archips rosaceana*) is found commonly on roses and various fruit trees, occasionally becoming injurious, while its

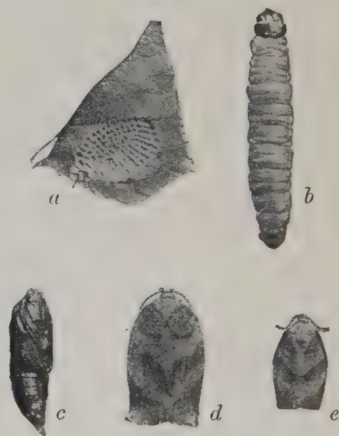

FIG. 289. The oblique-banded leaf-roller (*Archips rosaceana*). (Slightly enlarged)

a, egg-mass; *b*, larva; *c*, pupa; *d*, female moth; *e*, male moth

near relative, the cherry-tree leaf-roller (*A. cerasivorana*), festoons the branches of the wild and cultivated cherries with its large nests of leaves fastened together with silk, in which a whole brood of the yellow larvæ live and transform. Another group of this family includes the well-known codling moth (*Cydia pomonella*), the worst pest of the apple grower, and the eye-spotted bud moth (*Tmetocera ocellana*), which bores in the young buds of the apple, as well as numerous other larvæ which bore in the buds, terminal twigs, fruits, and seeds of various trees and plants.

FIG. 290. Web and empty pupal skins of the cherry leaf-roller (*Archips cerasivorana*). (Reduced) (Photograph by Weed)

FIG. 291. The codling moth. (Enlarged) (After Slingerland)

The pyralids. The third family, *Pyralidae*, includes some half dozen families of quite diverse appearance and habits, among which are the larger "micros," some of the largest having a wing expanse of one and one half inches and being larger than the smaller forms of the macrolepidoptera. Many of the caterpillars belonging to this group attack low-growing vegetation, the garden web-worm (*Loxostege similalis*) being one which now and then becomes a pest in various parts of the country, attacking garden crops, sugar beets and young cotton, and corn. The full-grown

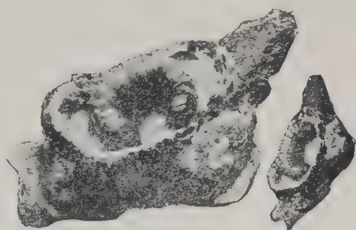

FIG. 292. Codling-moth larva in its winter cocoon under a bit of bark (Enlarged and natural size)

caterpillars are slightly over an inch long, yellowish or yellowish-green, marked with numerous shining black tubercles or warts, and may be recognized by the fine web which they spin over the food. The moths are of a yellowish-buff color, with darker markings (see Fig. 293). The melon caterpillar and the pickle-worm (*Diaphania hyalinata* and *nitidalis*) are serious crop pests in the Gulf States, though they occur farther north and in the West. The caterpillars are about an inch long, yellowish or greenish-yellow, and feed on the foliage, flowers, and fruit. Among the typical pyralids is the clover-hay worm (*Pyralis costalis*), which is abundant in stacks or mows of old clover hay, upon which it feeds and which is spoiled by being covered with its silken webs and excrement. The moth is of a lilac

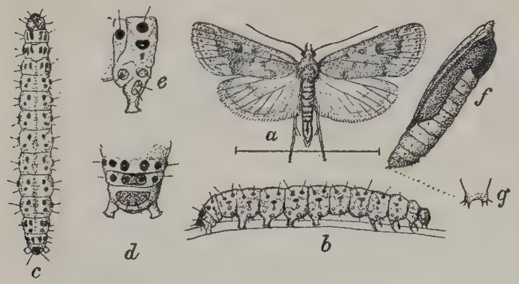

FIG. 293. The garden web-worm (*Loxostege similalis*)

a, male moth; *b*, larva, lateral view; *c*, larva, dorsal view; *d*, anal segment; *e*, abdominal segment, lateral view; *f*, pupa; *g*, cremaster. *a*, *b*, *c*, *f*, somewhat enlarged; *d*, *e*, *g*, more enlarged. (After Riley and Chittenden, United States Department of Agriculture)

FIG. 294. The meal snout-moth (*Pyralis farinalis* Linn.). (Twice natural size)

a, adult moth; *b*, larva; *c*, pupa in cocoon. (After Chittenden, United States Department of Agriculture)

color, with golden bands and fringes, and expands four fifths of an inch. The meal snout-moth (*Pyralis farinalis*) also sometimes feeds on clover hay, though it is more commonly a pest of meal and flour, in which it spins silken tubes wherever it feeds. A thorough

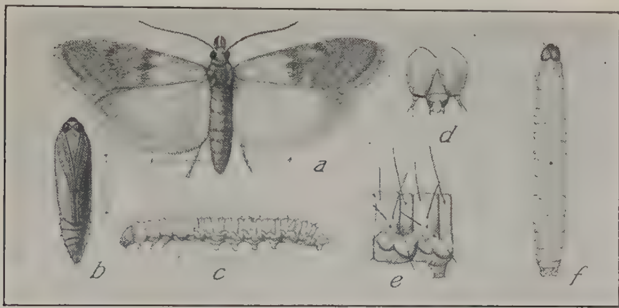

FIG. 295. The Indian-meal moth (*Plodia interpunctella*). (Enlarged)

a, moth; *b*, pupa; *c*, *f*, caterpillar; *d*, head; *e*, first abdominal segment of same. (After Chittenden, United States Department of Agriculture)

cleaning out of barns and grain rooms will usually prevent trouble from both of these pests.

The subfamily *Phycitinae* includes another pair of pests of grain products, — the Indian-meal moth (*Plodia interpunctella*), whose white larvæ spin silken tubes in meal, dried fruits, and other stores which they infest, and the Mediterranean flour-moth, which has similar habits and has become a very serious pest of flour mills, clogging up the machinery with its strong silken webs and necessitating frequent fumigation. The only common representative of another family is the bee-moth, whose larvæ feed upon the wax of honeycombs, in which they make

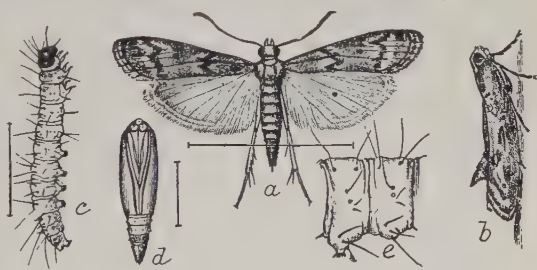

FIG. 296. The Mediteranean flour-moth (*Ephestia kuehniella*)

a, *b*, moth; *c*, larva; *d*, pupa (enlarged); *e*, abdominal segment of larva (more enlarged). (After Chittenden, United States Department of Agriculture)

silk-lined galleries, destroying the combs. They attack weak colonies of bees, which they frequently destroy, and are one of the worst enemies of the apiary. The moth has purplish-brown fore-wings and brown or faded yellow hind-wings.

FIG. 297. A crambid moth (*Crambus vulgivagellus*)

a, larva; *b*, overground, and *c*, underground, tube and cocoon; *d*, *e*, *f*, moths with wings open and at rest; *g*, egg much enlarged. (After Riley)

The close-wings (*Crambinae*) are so called because their wings are wrapped closely about them when at rest. They are also called snout-moths. They are the small brownish or silvery-white moths which fly up before us in pastures and are scarcely distinguishable from the grass stems on which they alight. The larvæ feed on the roots and stalks of grasses, living in little tubes constructed of bits of earth and vegetation fastened together with silk. Several species are sometimes quite injurious to young corn planted on land where they have been abundant, the most common being known as the corn-root web-worm.

FIG. 298. A California plume-moth. (Natural size)

(After Kellogg)

Two other families of this group are known as plume-moths (*Pterophoridae* and *Orneodidae*), as the wings are split into parts looking like a small fan of feathers. The larvæ of one species occasionally webs up the terminals of young grape shoots, and another species is sometimes common on sweet-potato vines, but they are rarely of economic importance.

MACROLEPIDOPTERA

Among the larger moths are two families whose larvæ bore into solid wood, though they are by no means nearly related.

The carpenter-moths (*Cossidae*) are medium-sized to large moths with spindle-shaped bodies and strong, narrow wings, thus closely

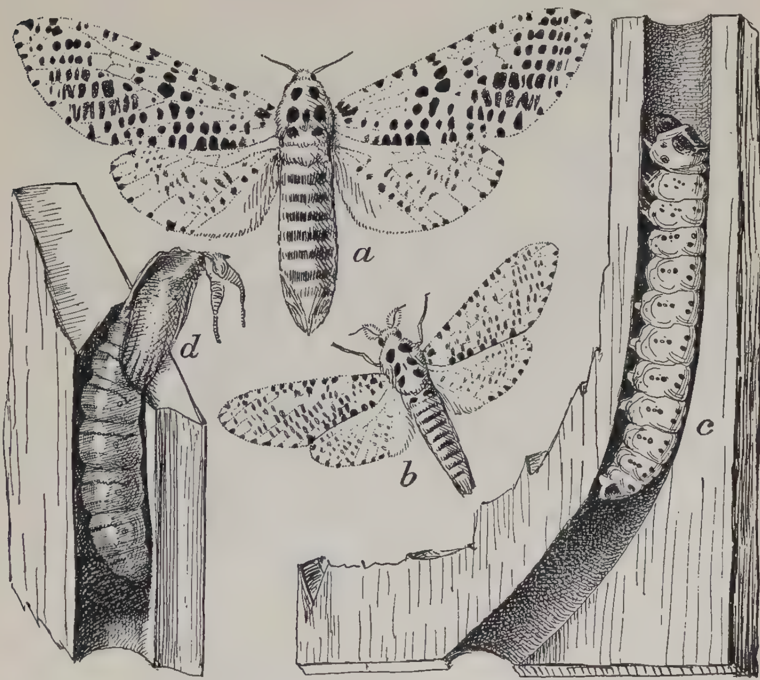

FIG. 299. The leopard moth. (Natural size)

a, female moth; *b*, male moth; *c*, larva in burrow; *d*, pupal skin from which moth has emerged. (From *Insect Life*, United States Department of Agriculture)

resembling the sphinx moths. The caterpillars are all wood borers, living from two to four years in the roots or trunks of trees. When full grown they are from two to three inches long, usually whitish, more or less black-spotted, with black heads bearing strong jaws. The female moth of a common species, which lives in the locust, has a wing expanse of three inches and is of a pepper-and-salt color. A recently imported European species is the leopard moth

(*Zeuzera pyrina*), which is seriously damaging the shade trees of Eastern cities to which it has spread. It is white, spotted with numerous black spots.

The clear-winged moths (*Sesiidae*). The caterpillars of the clear-winged moths also bore into the trunks and roots of trees and the stalks of smaller plants. The wings of the moths are quite narrow and are free from scales except along the margins and over the

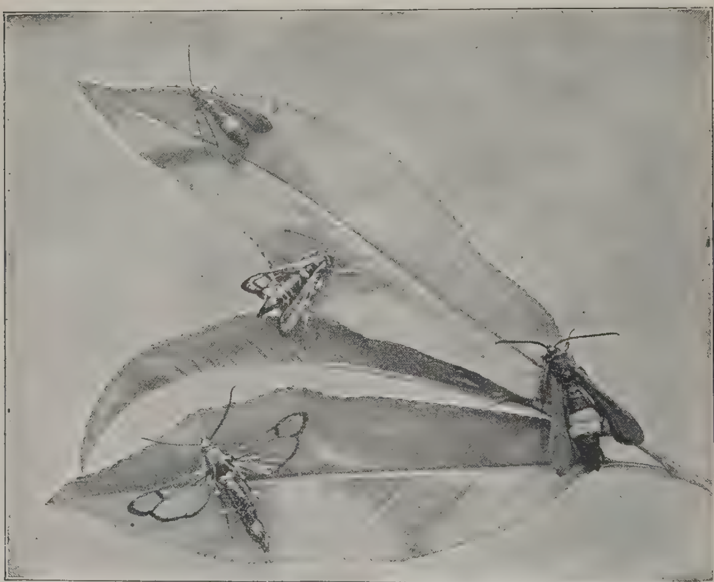

FIG. 300. Peach-tree-borer moths. (Natural size)

The upper one and one at right are females, the other two are males. (After Slingerland)

veins, leaving them quite transparent. The antennæ are long, and the body is long and slender, the abdomen being commonly banded with yellow and terminating in a tuft of scales. Unlike most moths they are found frequenting flowers in the daytime, and may very readily be mistaken for wasps, which they seem to mimic. The best-known example of the family is the peach-tree-borer (*Sanninoidea exitiosa*), whose white larvæ bore into the lower trunks and roots, being probably the worst insect enemy of the peach tree. The males are black with narrow yellow bands on the abdomen,

and with quite transparent wings, while the females are much larger, having fore-wings of a blackish brown and entirely covered with scales, and a black abdomen with a broad orange band about the middle. Other injurious species of clearwings, smaller and more wasplike than the peach-borer, are the currant-borer (*Sesia tipuliformis*), the raspberry root-borer (*Bembecia marginata*), and the well-known squash-vine borer (*Melittia ceto*) whose whitish larvæ bore through the vines of squash and other cucurbits, often ruining the crops. Not all clear-winged moths belong to this family,

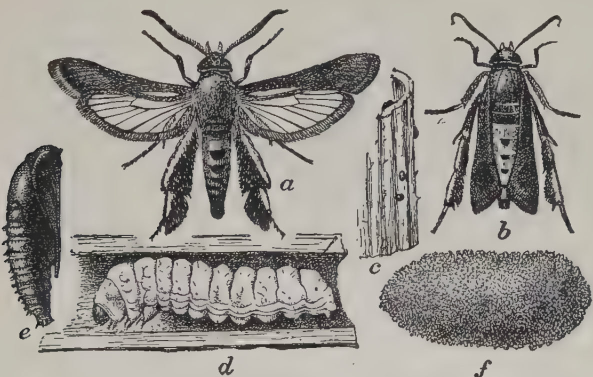

FIG. 301. The squash-borer (*Melittia satyriniformis* Hbn.). (Enlarged one third)

a, male moth; *b*, female with wings closed; *c*, eggs on squash stem; *d*, larva; *e*, pupa; *f*, cocoon

for a few of the sphinx moths (which, however, are much larger) and one or two other families have species with wings almost wholly free from scales.

The prominents (***Notodontidae***) are dull-colored, medium-sized moths, with a wing expanse of from one and one fourth to two inches, many of whose larvæ bear strong humps or prominences which may have given rise to the common name of the family. The moths quite closely resemble the owlet moths, from which they can be distinguished only by an examination of the wing venation. The handmaid moths are of a reddish-brown color, with the fore-wings crossed with several darker brown lines, whose larvæ have the peculiar habit of raising the head and tail and standing quite

motionless when disturbed, as shown in the illustration (Fig. 302) of the common yellow-necked apple caterpillar (*Datana ministra*), the specific name of which has given the group the common name of "handmaids." It is common on apple trees in late summer, the colonies of caterpillars stripping the foliage back from the tips of the twigs, and may be readily recognized by the black head, yellow neck, and black-and-yellow striped body. Nearly related species of blackish caterpillars covered with gray hairs often defoliate the hickory. The red-humped apple caterpillar (*Schizura concinna*) is associated with the above species on the apple and has very similar habits. It is of a yellowish-brown color, pale along the sides, which are marked with fine black lines; the head is red, the fourth segment bears a prominent red hump, and along the back there are many short spines. Several of the caterpillars of this family have irregular humps and prominences along the back and are of a green color, so that as they feed on the edge of a leaf they are not easily distinguished from the ragged leaf edge. Most of

FIG. 302. The yellow-necked apple caterpillar (*Datana ministra*). (Larvæ natural size and moth slightly enlarged)

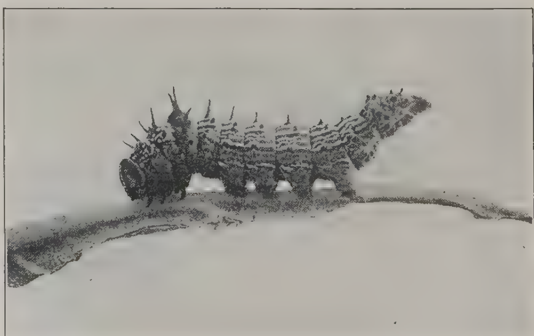

FIG. 303. The red-humped apple caterpillar feeding in characteristic position. (Natural size)

(After Britton)

FIG. 304. Antlered maple worms (*Heterocampa gutivitta*), showing variation in color markings. (Slightly enlarged)

our commonest species feed on shade and forest trees, but rarely do widespread damage. An exception to this is the case of the antlered maple worm (*Heterocampa gutivitta*), which stripped thousands of acres of maple and beech along the mountain sides from central Maine southwest to the Adirondacks in the summers of 1908 and 1909. These caterpillars are bright green with a saddle-shaped mark of purple, and when just hatched from the eggs have small, branched antlers just back of the head. The eggs of this family are laid on the foliage of the food plant, and the larvæ descend to the ground to pupate, the pupæ usually remaining in the soil over winter.

FIG. 305. Red-humped oak caterpillars (*Symmerista albifrons*) on oak leaf. (Reduced)

The measuring-worms (family *Geometridae*) are the caterpillars of a large family; they have but one or two pairs of abdominal prolegs, so that as the middle of the body is unsupported they are unable to walk like ordinary caterpillars, but loop along in a characteristic fashion, which has given them the common name of "inch-worms" or "measuring worms." Many of them will stand with the body stretched out stiff and motionless, so that they are readily mistaken for broken twigs and are probably passed over by birds seeking food. Although there are no absolutely distinctive characters by which the

FIG. 306. Moth of the red-humped oak caterpillar

(After Weed)

FIG. 307. Caterpillar of *Nerice bidentata* feeding on leaf, showing resemblance of contour to edge of leaf

(After Packard)

FIG. 308. The chain-dotted geometer feeding on sweet-fern. (Slightly reduced)

moths may be readily recognized, their slender bodies, small heads, and broad wings, which are usually noticeably thin and frail, give them a characteristic appearance. They frequent forests and edges of woodlands, and though a few are orchard pests, and others affect the bush fruits, nearly all of the caterpillars feed upon the foliage of forest or shade trees, and but few frequent low-growing vegetation. The moths vary from less than an inch to over two inches in wing expanse, but are mostly of medium size. The wings remain spread when at rest. Possibly the best-known examples are the cankerworms, which attack the foliage of fruit and shade trees in early spring and drop down from the trees on their silken threads. The females of the cankerworms and some nearly related species are wingless and look much more like fat spiders than moths. The chain-dotted geometer (*Cingilia catenaria*) is a snow-white moth marked with zigzag lines and dots of black. Its larvæ feed on various low-growing shrubs and trees and sometimes appear in great numbers, as was the case in New Hampshire in 1906, when many acres of sweet fern and scrub birches were stripped. The larvæ are of a bright straw yellow,

FIG. 309. The chain-dotted geometer (*Cingilia catenaria*); larva; larva spinning cocoon; pupa in cocoon; moth. (Slightly enlarged)

FIG. 310. The apple-tree measuring worm (*Ennomos subsignarius*). (Natural size)
a, adult; *b*, eggs; *c*, *e*, larvæ (natural size and enlarged); *d*, pupæ. (After Garman)

marked with six black lines and with a black dot on the side of each segment. The currant span-worm (*Diastictis ribearia*) is a yellow, black-spotted looper, which often appears in such numbers on currant and gooseberry bushes as to defoliate them very quickly. The moths are pale yellow, marked with irregular, dusky spots. Most of the moths of the subfamily *Geometrinae* are of a green color with the wings barred more or less distinctly with whitish lines. The larvæ of one of these, the raspberry geometer (*Synchlora glaucaria*), feeds on the fruit and foliage of the raspberry, covering itself with bits of vegetable matter, thus masking itself beneath what is apparently a little heap of rubbish.

FIG. 311. Adult female moth and egg mass and winged male of the fall cankerworm. (Natural size)

(After Britton)

The owlet-moths (*Noctuidae*) are by far the largest family of the order, including some twenty-one hundred species, "three times as many as there are North American species of birds," and form the great bulk of the moths commonly taken by collectors. As their name indicates, they fly by night (as do all other moths, for that matter) and are frequently attracted to lights, being the common "millers" of popular parlance. They are not readily distinguished from nearly related families, nor are the species recognizable

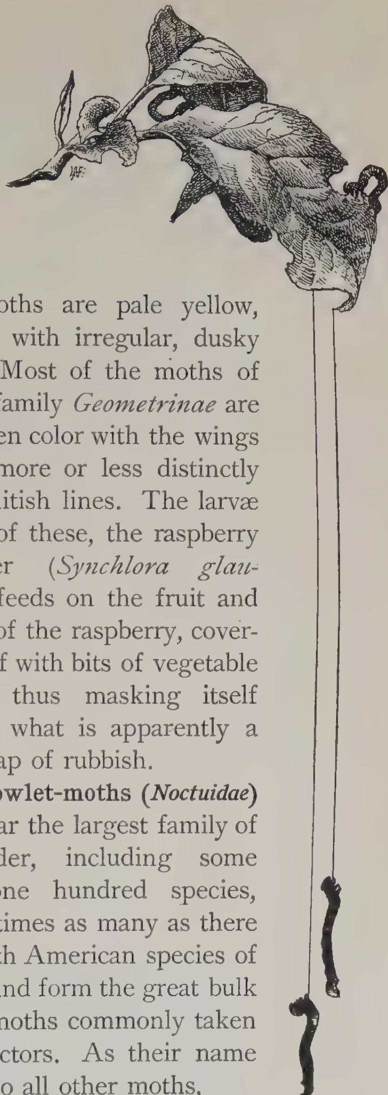

FIG. 312. Cankerworms in characteristic attitudes. (Natural size)

(After Bailey)

FIG. 313. *Drasteria erechtea*, female

except by an expert, though many of their caterpillars are the worst pests of the farm and garden and are well known as such to the farmer. The moths are mostly somber gray or brown, with a wing expanse of from one to three inches (averaging about one and one half inches), and with stout bodies. The fore-wings are rather narrow, short, and stout, crossed by darker or lighter wavy lines, and with one or two darker or lighter spots toward the center. The hind-wings are usually plain, and when at rest are concealed by the fore-wings, which cover them, either flat on the back or slightly roof-shaped. Some of the caterpillars are hairy like the "woolly bears," but most of them are smooth, dull-colored "worms," obscurely striped, as are the common cutworms. Almost all of the larvæ feed on low-growing vegetation and pupate in the ground. Among the moths most often observed are those of the northern grass worm (*Drasteria erechtea*). They are the common moths with drab-gray fore-wings, crossed with two dark bands, which fly up as one crosses a meadow or pasture. The larvæ are green, narrowly striped, and are semiloopers, somewhat resembling the measuring worms in their gait. They feed on clover, but rarely become injurious. The common cutworms which attack garden and field crops throughout the country are the larvæ of numerous

FIG. 314 *a*. Moth of the army-worm (*Leucania unipuncta*). (Natural size) (After Riley)

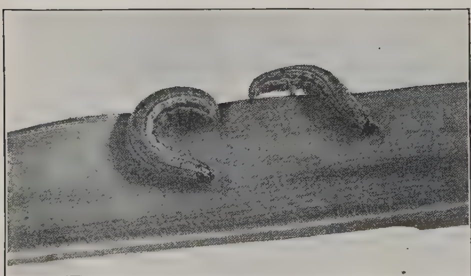

FIG. 314 *b*. Army-worms. (Natural size) (After Weed)

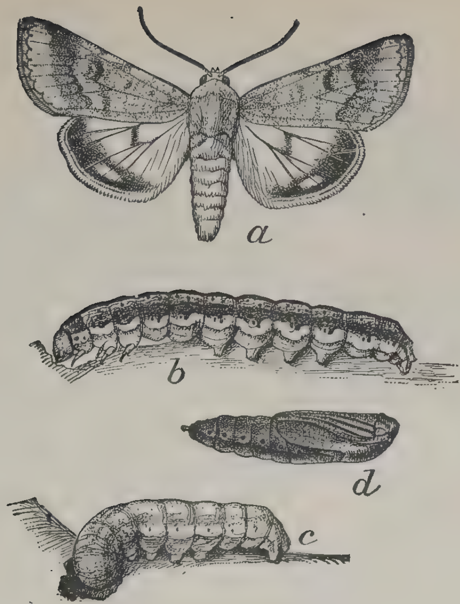

FIG. 315. The cotton bollworm, or corn-ear worm (*Heliothis obsoleta*). (Natural size)

a, adult moth; *b*, dark full-grown larva; *c*, light full-grown larva; *d*, pupa. (After Howard, United States Department of Agriculture)

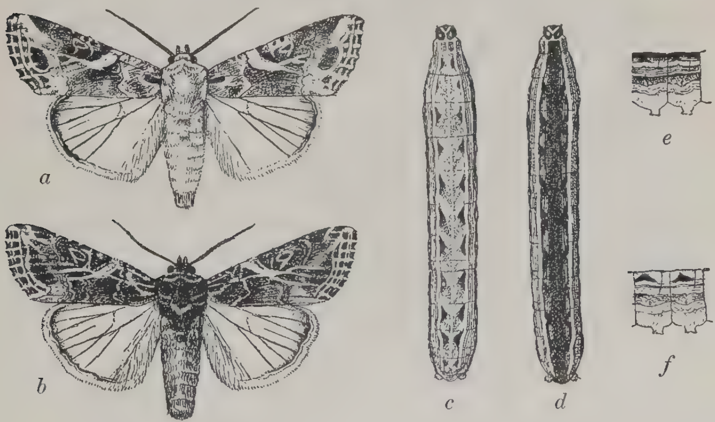

FIG. 316. The cotton-boll cutworm (*Prodenia ornithogalli* Guen.). (Enlarged)

a, dark form of male moth; *b*, pale form of female moth; *c*, pale form of larva; *d*, dark form of same; *e*, lateral view of abdominal segments of dark form; *f*, of pale form. (After Chittenden, United States Department of Agriculture)

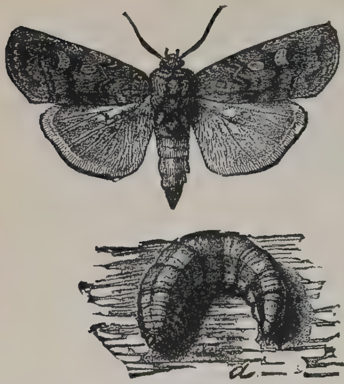

FIG. 317. The dark-sided cutworm (*Agrotis messoria*)

(After Riley)

species of moths of this family, belonging to several genera. The army-worm (*Leucania unipuncta*) is another caterpillar which ordinarily feeds unnoticed on rank grasses, but occasionally becomes very numerous and advances in armies, destroying all crops in its line of march. The fall army-worm (*Laphygma frugiperda*) has very similar habits, but is more common in the South and West. Two of the most serious cotton pests are the leaf worm (*Aletia argillacia*) and the bollworm (*Heliothis obsoleta*), although the latter also attacks the ears of corn, tobacco, and green tomatoes throughout the Middle States. A common pest of cabbage and lettuce is the cabbage looper (*Autographa brassicae*), a bright green worm with whitish lines, which bores into cabbages much like the common caterpillars of the cabbage butterfly. It is known as a looper on account of the way in which it "humps" along, much like a measuring worm, because two pairs of the usual abdominal prolegs are lacking. Some of the larger species of this family, with a wing expanse of from two to three

FIG. 318. The cabbage looper

a, male moth; *b*, egg shown from above and from side; *c*, full-grown larva in natural position, feeding; *d*, pupa in cocoon. *a*, *c*, *d*, one third larger than natural size; *b*, more enlarged. (After Howard and Chittenden, United States Department of Agriculture)

inches, of the genus *Catocala,* have mottled gray fore-wings which very closely resemble the bark of trees, upon which they rest during the day. The hind-wings are black, brilliantly banded with red or yellow. They are much fancied by collectors and are taken by luring them with sugar water or similar lures, smeared on the trees.

FIG. 319. *Catocala ultronia* and its larva
(After J. B. Smith)

The tussock-moths (***Liparidae***). The caterpillars of the tussock-moths are strikingly clothed with tufts of bright-colored hairs, or tussocks, which has given them their popular name. The moths are medium sized, usually of a dull brown or gray color. The males have feathered

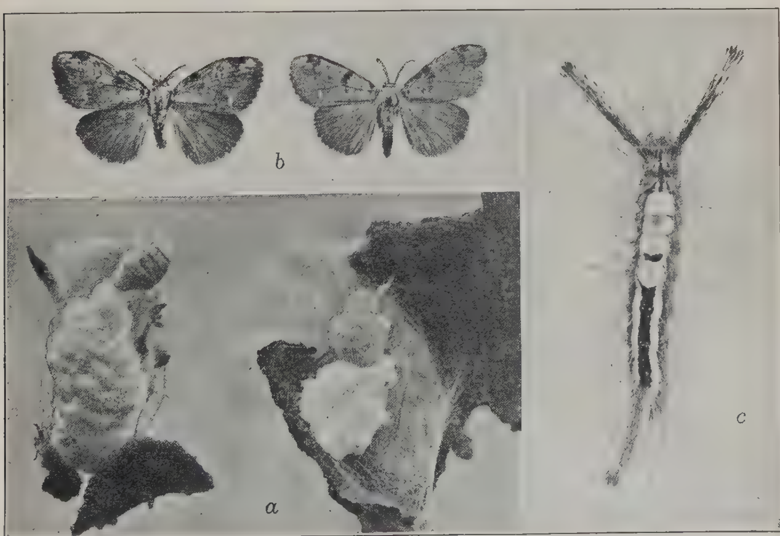

FIG. 320. The white-marked tussock-moth. (Natural size)
a, wingless females depositing eggs on cocoons; *b*, male moths; *c*, full-grown female larva

antennæ. The females of our common species, of which the white-marked tussock-moth (*Hemerocampa leucostigma*) is a good example, are wingless and look more like hairy grubs or fat spiders than moths. These wingless females pair as soon as they emerge from the cocoons, and then lay their eggs upon them and die. The eggs of this species are usually found on the trunks of trees, and are covered with a white substance looking like frosting. The caterpillar is about one and one half inches long, with a pair of black pencils of hairs projecting a half inch forward on either side of the head, and a single pencil of similar length extending from the tip of the abdomen. The head and a small glandular dot on the center of the sixth and seventh abdominal segments are bright red, the body is yellow banded with black, and the first four abdominal segments bear brushlike tufts of white hairs. This species often becomes a serious pest of shade and fruit trees, while nearly related species are common but not so injurious. To this family belong the gypsy moth (*Porthetria dispar*) and the browntail moth (*Euproctis chrysorrhoea*), both of which have been imported from Europe into New England, where they have done enormous damage to trees of all kinds. The male gypsy moth is tawny brown, with black markings, while the female is much larger, and is white, with wavy blackish lines across the wings. The female is unable to use her wings for flight, and lays her eggs on

FIG. 321. Male and female gypsy moths. (Natural size)

(After Forbush and Fernald)

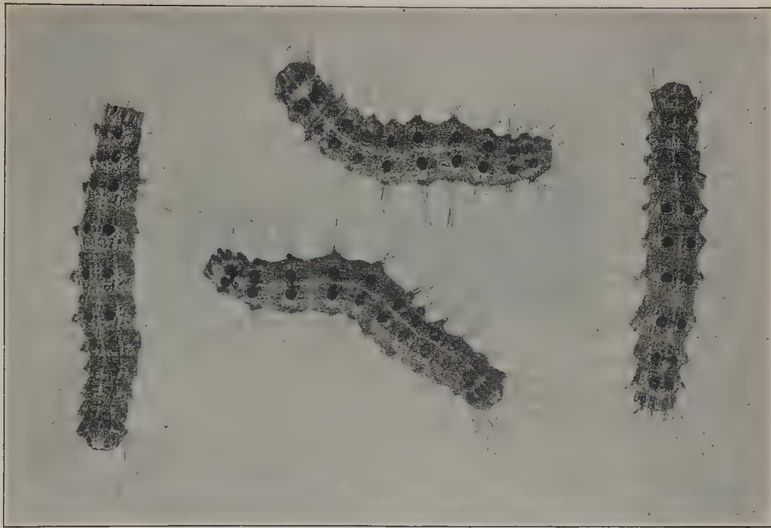

FIG. 322. Gypsy-moth caterpillars. (Natural size)
(After Britton)

the bark near the cocoon. The caterpillar is two and one half inches long when full grown, of a dark, sooty color, somewhat hairy, and with a double row of five pairs of blue and six pairs of red tubercles down the middle of the back, which distinguish it from all other common caterpillars. The brown-tail moths are pure white, with a brown tuft of hairs at the tip of the abdomen, more prominent in the female. Both sexes are strong flyers and are carried readily by the wind. The eggs are laid in a mass on the foliage and are covered with brown hairs from the tip of the female's abdomen. They hatch early in August, and after feeding two or three weeks the little caterpillars draw the leaves together at the tips of the

FIG. 323. The brown-tail moth, male and female. (Natural size)

branches with strands of silk and in them spin little silken cells, the whole forming a strong web, within which they pass the winter and emerge to complete their growth in the spring. The caterpillars defoliate fruit and shade trees, but never attack conifers, as do the partly grown gypsy-moth caterpillars. They are one and one half inches long, of a dark brown color marked with patches of orange, and covered with numerous long, barbed hairs. On the side of each segment is a characteristic white dash, and the little red spots characteristic of this family are found on the center of the sixth and seventh abdominal segments. The tubercles along the back and sides are thickly covered with short brown hairs, the masses having a velvety appearance. These are the nettling hairs, which, when they alight on the skin, produce an eruption very similar to that caused by poison ivy, and which is so painful and annoying that, where the caterpillars become abundant, they render life miserable for the inhabitants during early summer. As the nests of this pest have been imported on pear seedlings by nurserymen in almost every state during the past two years, it will be remarkable if it is not soon found outside of New England, and should be constantly watched for, so that it may be brought under control at once before it spreads. This family is a small one, and has almost no species of economic importance in this country other than those mentioned.

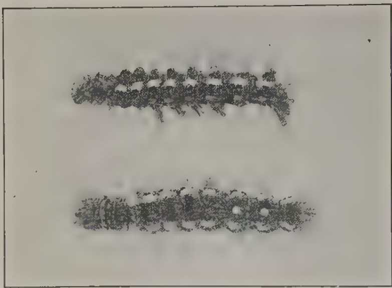

FIG. 324. The brown-tail-moth caterpillar, from side and back. (Natural size)

FIG. 325. Winter web of the brown-tail-moth caterpillars (Reduced)

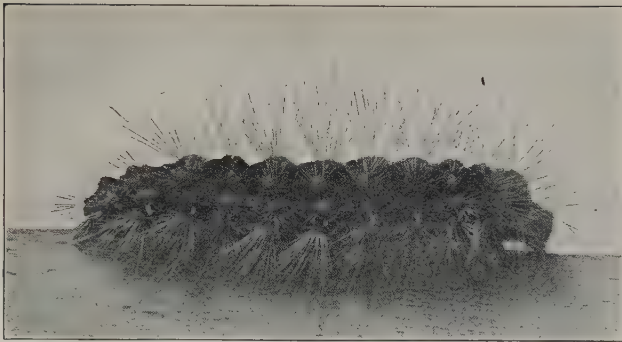

FIG. 326. The salt-marsh caterpillar (*Estigmene acraea*), one of the "woolly bears"

The tiger-moths (*Arctiidae*) are well named, for many of them are conspicuously striped or spotted with orange, red, or black. Among the larvæ are the well-known hairy "woolly bears," which crawl across the walks in late fall and early spring, faithful harbingers of winter and summer. The moths are frequently attracted to lights, when their brilliant colors always command attention. On some of the larvæ the hairs are massed into brushes much like those of the tussock-moths, as is the case with the common harlequin milkweed caterpillar (*Cycnia egle*), which is clothed with tufts of orange, black, and white hairs, and is the most common caterpillar on the milkweed. Our most common species is possibly the Isabella tiger-moth

FIG. 327. The hickory tiger-moth (*Halesidota caryae*) and its larva

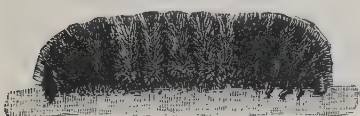

FIG. 328. The common red-and-black caterpillar of the Isabella tiger-moth (*Pyrrharctia isabella*)

(After Comstock)

(*Pyrrharctia isabella*), whose hairy larva is reddish-brown in the middle and black at either end. It does but little harm, but is the species commonly seen on walks in fall and spring, so that it is well known. The fall web-worm is the common caterpillar which covers our fruit trees with its unsightly webs in late summer. The moths are pure white or spotted with black. The caterpillars vary from yellowish to blackish, with darker lines and spots, and are covered with long hairs. Most of the caterpillars of this family feed on low-growing vegetation and weeds; several now and then become overabundant and attack garden crops.

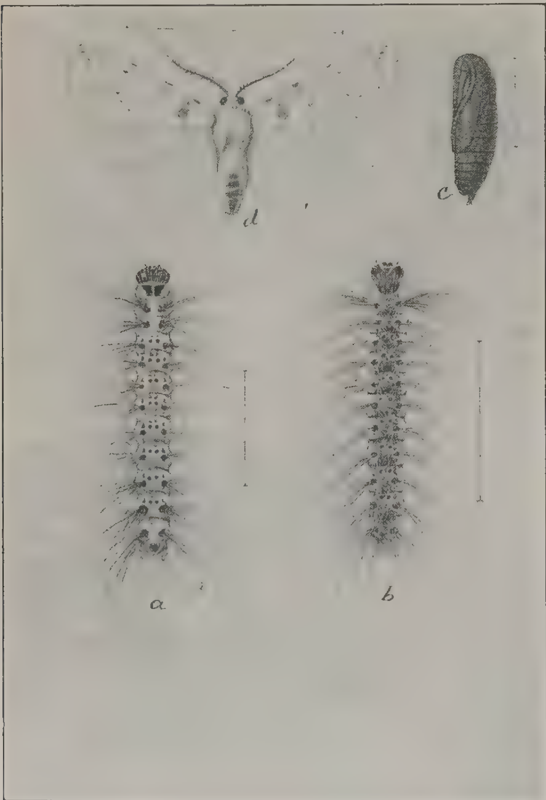

FIG. 329. The fall web-worm. (All slightly enlarged)

a, light form of full grown larva; *b*, dark form of same; *c*, pupa; *d*, spotted form of moth. (After Howard, United States Department of Agriculture)

The hawk-moths (*Sphingidae*) are sometimes called humming-bird moths, for the larger species are fully as large as a humming bird, with three to five inches wing expanse, and are frequently found hovering over petunias and similar flowers on warm summer evenings. They are easily recognized from their long, spindle-shaped bodies, strong, narrow wings, and thick, prismatic antennæ, which are often curved back at the tip, forming a slight hook. The

proboscis is very long, in some species being twice as long as the body, and is coiled up under the head like a watch spring. Many of the caterpillars are known as hornworms, from the strong horn on top of the last segment, which is quite characteristic of the family, though in some cases it is replaced by a bright, glassy eyespot. "When at rest," says Dr. J. B. Smith, "some of them have the habit of elevating the front part of the body and curling the head under a little, giving them a fancied resemblance to a *sphinx*, and from this the scientific name has been derived." A well-known example of this family is the large green tobacco or tomato worm (*Phlegethontius quinquemaculata*), which rags the foliage of these plants, and is the tobacco grower's worst enemy. It has slanting white stripes along its sides, and, when fully grown, is about three inches long; then it goes underground and transforms to a mahogany brown pupa from one and one half inches to two inches long, bearing a peculiar handlelike process bent back from the head, which has given it the names of "jug-handle grub" and "hornblower." The pupæ remain in the soil over winter, and the moths emerge the next spring, there being two broods a season in the North and three or four in the South. The adults are among our most handsome moths, the wings expanding from three to five inches, ashen-gray in color, the fore-wings crossed by irregular darker lines with a white spot near the center, and the hind-wings

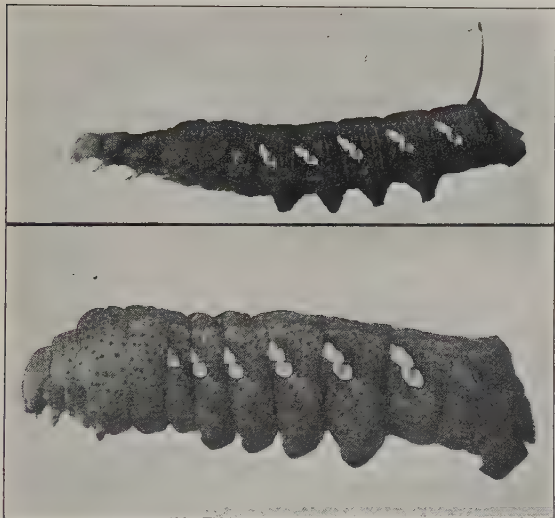

FIG. 330. Larvæ of achemon sphinx

Above, young larva with head extended and with caudal horn (enlarged); below, full-grown larva with head partly drawn in (natural size)

Fig. 331. Typical sphinx moths (*Deilephila lineata* Fab. above and *Pholus achemon* below)

(After Lugger)

Fig. 332. Southern tobacco-worm moth. (Natural size)

(After Britton)

banded with black and white, while along the sides of the abdomen are five large yellow spots. The grapevine hog caterpillar (*Ampelophaga myron*) is typical of a series of species in which the caudal horn of the larva is lost and replaced by an eyespot; the first two thoracic segments are much smaller and, with the head,

FIG. 333. Southern tobacco-worm. (Natural size)
(After Britton)

are retracted into the metathorax. This has given some one the idea that they resemble fat porkers, — hence the name "hog caterpillars." This larva is common on the grape and woodbine and is about two inches long, with a row of seven reddish or lilac spots set on a yellow background along the middle of the back, and a white stripe down each side, below which are seven oblique stripes. It is quite variable in color and is very commonly infested with braconid parasites (see page 251), whose cocoons are frequently found covering the caterpillars. Some of the smaller moths of this family have the wings nearly bare of scales, like the clear-winged moths, and, like them, fly around flowers during the day. The larger ones are often called humming-bird hawk-moths, while the smaller

FIG. 334. A clear-winged sphinx moth, or bee-moth (*Hemaris thysbe*)

ones look quite like large bumblebees. They are readily recognized as belonging to this family by the form of the body, wings, and antennæ.

The saturnians (superfamily *Saturnoidea*) include some forty-two species of our largest silkworm moths, divided into four families, which need not here be distinguished. The large, brilliantly colored larvæ are readily reared, and from the cocoons are secured the handsome moths which are the pride of every collector. The males of this group are easily distinguished from the females by their broadly feathered antennæ. The most important economic species

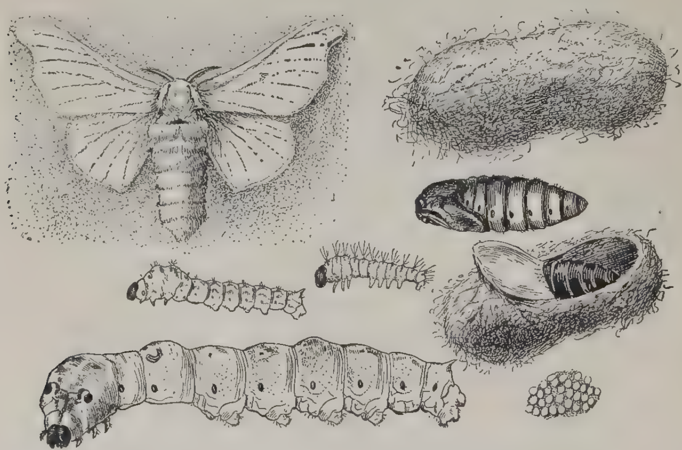

FIG. 335. Life history of silk moth (*Bombyx mori*): adult; caterpillars of different ages; silken cocoons; pupa; eggs. (Natural size)

(After Jordan and Heath)

of the group is the silkworm (*Bombyx mori*), which is reared in Europe and Asia for its silk, furnishing all the silk of the world. It has been frequently introduced into this country, but, although it can be grown here, its commercial culture has never proved successful. It is one of the smaller moths of the group, expanding one and one half inches, the wings being of a cream color, with two or three brownish lines across the fore-wings. The larvæ are of a creamy white color and feed on the leaves of the mulberry. Another small species which often defoliates our maples is the green-striped maple-worm (*Anisota rubicunda*). The caterpillars are one and one half inches long, yellowish-green, striped with eight lighter lines

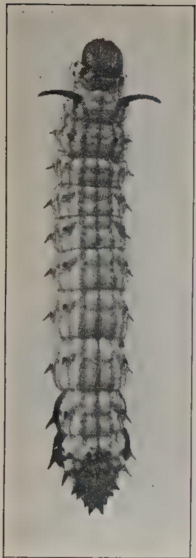

FIG. 336. The green-striped maple-worm (*Anisota rubicunda*)

alternating with seven darker, almost blackish lines, with two prominent black horns on the thorax and a double row of short, thick spines along each side of the body. The moths are pale yellow banded with rose color, and are frequently taken at lights. Nearly related species, whose larvæ are brownish with orange markings and similar black spines, attack the oak foliage. The Io moth (*Automeris io*) is one of the larger forms, with a wing expanse of nearly three inches, the fore-wings of the males being a brilliant yellow color and those of the female a dark purplish, both having a large eyespot on the center of the hind-wings. The full-grown larva is about two inches long, yellowish-green, with a broad brown or reddish stripe, edged with white, along either side, thickly covered with black-tipped, branched spines which are decidedly poisonous. The polyphemus moth (*Telea polyphemus*) is one of our largest and handsomest species, expanding from four to five inches. It is of a yellowish or brownish color, with a dusky band, edged without with pink along the margins of both wings, and with a prominent eyespot at the middle of each wing, those on the hind-wings being bordered by a large bluish patch. The larvæ feed on oak and various fruit and shade trees; they are three inches or more in length, of a bright green color, with an oblique yellow line on the side

FIG. 337. The Io moth, female. (Natural size)
(After Lugger)

FIG. 338. Io moth caterpillar

FIG. 339. *Telea polyphemus* caterpillar

FIG. 340. *Telea polyphemus* moth and cocoon. (Reduced)

(After Lugger)

of each abdominal segment, and with numerous small orange-colored tubercles with metallic reflections. The cocoon is oval, usually wrapped in a leaf, and is attached to the twigs of trees and shrubs. The luna moth (*Actias luna*) is a brilliant green species with long tails projecting from the hind-wings; it is frequently attracted to lights on warm evenings of early summer. Each wing bears a small eyespot, and the anterior margin of the fore-wings is purplish. The larvæ feed on the leaves of walnut, hickory, and forest trees. Possibly our most common species is the cecropia moth (*Samia cecropia*) whose long brown cocoons are frequently found on fruit and shade trees. The moths are a dusky, reddish brown, and may be readily recognized from Fig. 341. The caterpillar is three or four inches long, of a bright green color, with six prominent tubercles on the thoracic segments, — the first four coral-red and the hinder two yellow, — and with smaller, similar yellow tubercles on the back of the abdominal segments. They feed commonly on fruit and shade trees, but are never numerous enough to do much damage. The cocoons of a

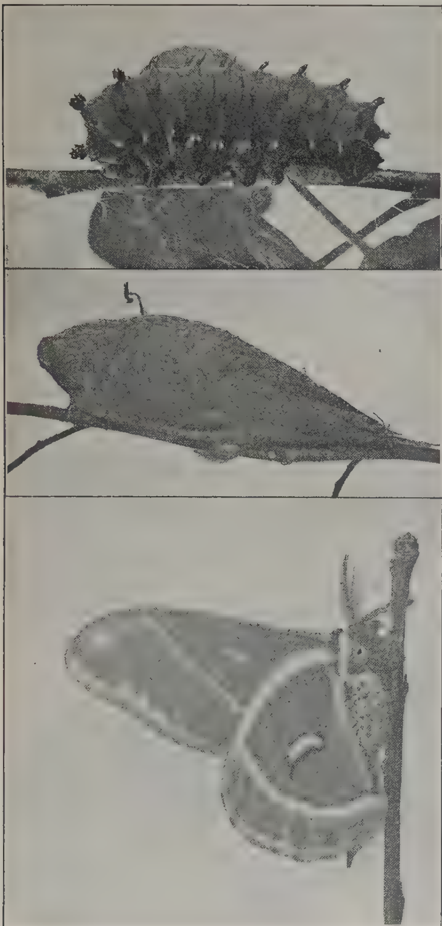

FIG. 341. The cecropia moth (*Samia cecropia*), larva, cocoon, and moth at rest. (All reduced)
(Photograph by Weed)

FIG. 342. The promethea moth (*Callosamia promethia*). (Reduced)

(Photograph from life by Weed)

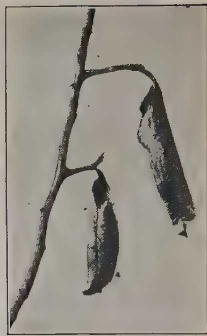

FIG. 343. Pendent cocoons of promethea moth. (Greatly reduced)

nearly related species (*Callosamia promethia*) hang pendent from the twigs of wild-cherry, ash, willow, and other trees. Although many attempts have been made to manufacture the silk in the cocoons of these native species, they have so far been unsuccessful.

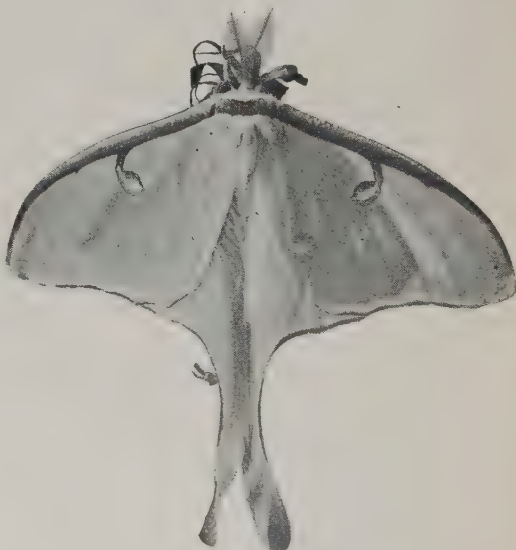

FIG. 344. Luna moth (*Actias luna*). (Reduced)

(Photograph from life by Weed)

Our common tent caterpillar, which is fully described on page 57, is a representative of a family of this group (*Lasiocampidae*), though much smaller in size than the preceding, having a wing expanse of one and one half inches.

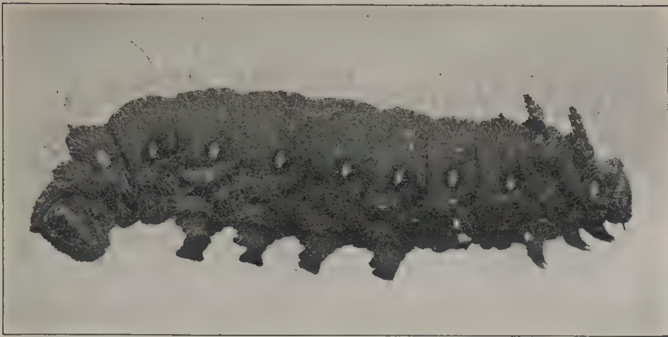

FIG. 345. Caterpillar of the imperial moth (*Basilona imperialis*). (Natural size)

SUMMARY OF THE LEPIDOPTERA

BUTTERFLIES. Day flyers. Antennæ clubbed. Wings held vertically.
- Skippers (*Hesperina*). Antennæ hooked.
- True butterflies (*Papilionina*).
  - Swallowtail butterflies (*Papilionidae*).
  - White and yellow butterflies (*Pieridae*).
  - Gossamer-winged butterflies (*Lycaenidae*).
  - Four-footed butterflies (*Nymphalidae*).

MOTHS. Night flyers. Antennæ not clubbed. Wings held flat.
- Microlepidoptera.
  - Family (*Tineidae*). Leaf-miners, clothes moths, etc.
  - Family (*Tortricidae*). Leaf-rollers, bud-borers, etc.
  - Family (*Pyralidae*). Leaf-folders, meal-worms, close-wings, bee-moth, etc.
- Macrolepidoptera (in part).
  - Carpenter-moths (*Cossidae*). Larvæ wood borers.
  - Clear-winged moths (*Sesiidae*). Larvæ wood borers.
  - Prominents (*Notodontidae*).
  - Measuring-worms (*Geometridae*).
  - Owlet-moths (*Noctuidae*).
  - Tussock-moths (*Liparidae*).
  - Tiger-moths (*Arctiidae*).
  - Hawk-moths (*Sphingidae*).
  - Saturnians (superfamily *Saturnoidea*). Silkworm moths. Tent-caterpillar moths.

CHAPTER XIV

FLIES, MOSQUITOES, AND MIDGES (*DIPTERA*)

Characteristics. Insects with one pair of wings borne by the mesothorax; the hind-wings represented by a pair of knobbed threads, called halteres; mouth-parts, suctorial; metamorphosis, complete.

Ordinarily all sorts of small insects with membranous wings are indiscriminately called *flies*, and the term "fly" has been used to form part of a compound name for insects of several different orders, such as May-fly, sawfly, gallfly, butterfly, etc., but, considered from the entomological standpoint, a fly is a two-winged insect of the order *Diptera*. With this in mind, it is always easy to distinguish flies, as no other order has a *single* pair of wings (except the male scale insects), and the name of the order becomes significant, being derived from *dis* (two) and *pteron* (wing). The hind-wings are replaced by a pair of odd, club-shaped organs, called balancers, or halteres, which seem to be concerned with maintaining the equilibrium of the insect and are, of course, peculiar to this order. A few of the parasitic families are wingless. The mouth-parts have already been referred to (see page 18) and are fitted for sucking the juices of plants and animals, though in some there are strong, lancelike mouth-parts fitted for piercing, while in others a large, fleshy proboscis, fitted for rasping and lapping, is developed.

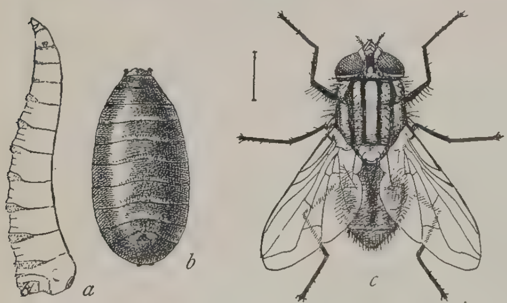

FIG. 346. The house-fly. (Enlarged)

a, larva, or maggot; *b*, puparium; *c*, adult. (After Howard, United States Department of Agriculture)

The transformations are always complete. The most common larvæ are termed "maggots," and are headless and footless, white, or light-colored, tapering to a point at the head, usually with a horny, rasplike feeding organ retruded within the head, though many absorb nutriment from the surrounding food through the skin. In other larvæ the head and mouth-parts are well developed, while some, like the mosquito wrigglers, lead a most active life. The pupæ are usually naked or inclosed in the last larval skin, though a few make cocoons. Instead of being molted, the last larval skin of most common flies becomes hard and distended, and the pupa separates within it, so that the larval skin practically forms a cocoon for the pupa and is known as a puparium, which looks much like a large brown or black seed.

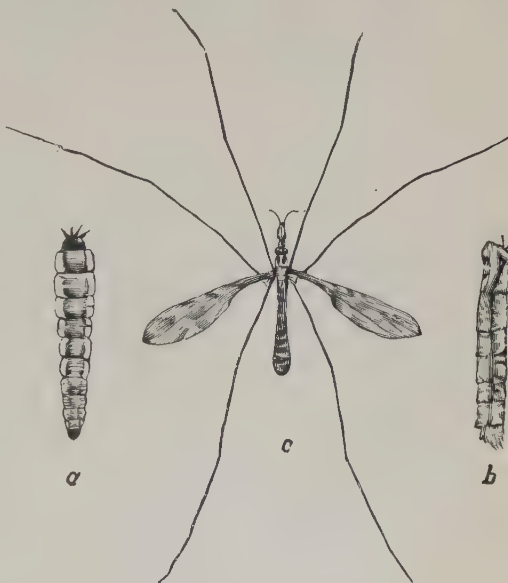

FIG. 347. A crane-fly (*Tipula hebes* Loew)
a, larva, or meadow-maggot; *b*, pupa; *c*, adult male fly. (After Weed)

The Diptera is one of the largest orders, with over five thousand species in this country (a great majority of which may be classed as injurious), and includes many serious crop pests and most of the insects which carry disease. The different families are distinguished by the structure of the antennæ and of the wing veins, and are divided into two suborders, the typical Diptera (*Diptera genuina*), including all the common families, and the *Pupipara*, including three small families of parasitic species, mostly wingless.

I. Typical Diptera (*Diptera genuina*)

Disregarding characters of the puparium which are not readily observable, the typical Diptera are divided into two series of families, based upon the length of the antennæ, known as the Long-horned Diptera, which have more than five antennal segments, and the Short-horned Diptera, having not more than five segments.

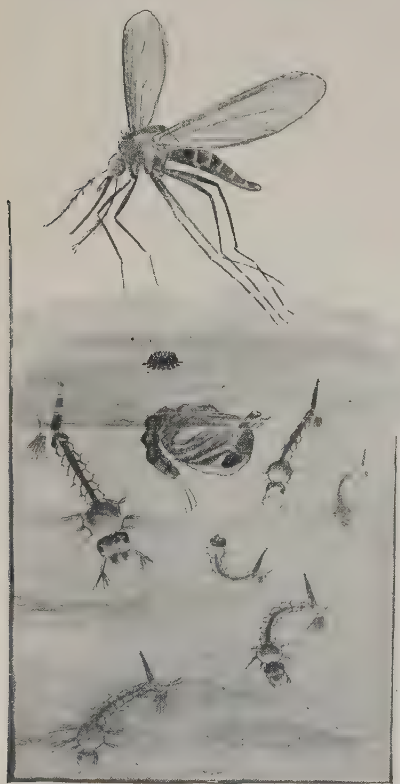

Fig. 348. Life history of a mosquito (*Culex* sp.). (Much enlarged)

On the surface of the water, a small raft of eggs; in the water, several long, slender larvæ (wrigglers) and one large-headed pupa (tumbler); above the water, an adult. (From life, after Kellogg)

LONG-HORNED DIPTERA (*NEMATOCERA*)

The crane-flies (*Tipulidae*) are easily recognized by their long, slender bodies, narrow wings, and exceedingly long, fragile legs, which characteristics have given them the name "granddaddy-long-legs," a name more correctly applied to the harvestmen, which are round-bodied spiders with very long legs. The maggots of crane-flies, sometimes called leather-jackets, or meadow-maggots, are dirty white, with a tough skin, and feed upon the roots of plants, decaying vegetable matter, and fungi. They are frequently found in the decaying wood and mold in the crotch of an old tree or in a stump, while several species which feed on their roots sometimes become abundant enough to do considerable damage to grasses and grains. The adults are among our largest flies, the common species

having a wing expanse of from one and one half to two inches. The giant crane-fly (*Holorusia rubiginosa*), of California, is the

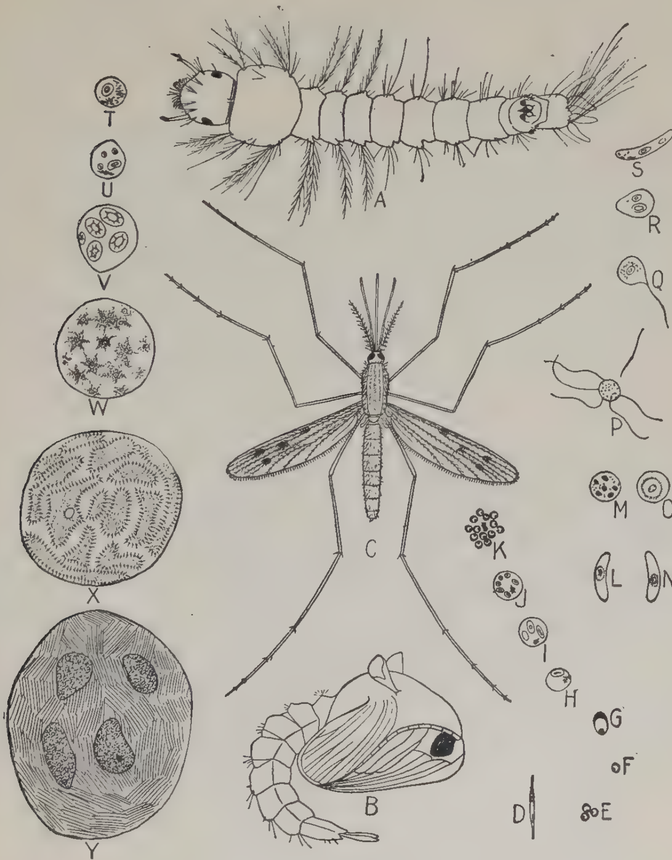

FIG. 349. *Anopheles* mosquito and malaria

a, larva; *b*, pupa; *c*, adult; *d*, the blast introduced into the blood by the mosquito; *e* to *j*, stages through which the plasmodium passes in the red blood corpuscle; *k*, the spores which enter new blood corpuscles; *l*, *m*, the microgamete; *n*, *o*, the macrogamete; *p*, flagellæ forming; *q*, union of a flagellum with macrogamete; *r*, fusion of nuclei; *s*, the vermicule; *t* to *y*, formation of the zygote in the mosquito stomach, the fully developed zygote, *y*, rupturing to produce blasts. (After J. B. Smith)

largest species of the order, being two inches long and the legs spreading some four inches. What advantage the crane-flies derive from their size is a question, as they are very awkward and fragile.

The mosquitoes (*Culicidae*) are so well known as to need no description, but there are many mosquitolike flies which might easily be confused with them. They have the mouth-parts developed into a strong proboscis fitted for piercing, and the antennæ of the males are strongly plumose (see Fig. 53); but the most distinctive character consists of a fringe of scales along the margin of the wing and also along the wing-veins, which can be readily seen with a lens. The eggs are laid in small masses on the surface

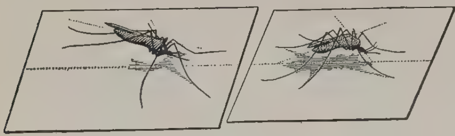

FIG. 350. Resting positions of *Anopheles* and *Culex* mosquitoes. (Slightly enlarged) (After Grassi)

FIG. 351. The yellow-fever mosquito (*Stegomyia calopus*). (Enlarged) (After Howard, United States Department of Agriculture)

of quiet or slow-moving water, and hatch in from one to four days. The larvæ are the well-known wrigglers of ponds and ditches, with their characteristic long, squirming bodies, thick head end, and

forked abdomen. They breathe through the respiratory tube projecting upward from the abdomen, which is thrust through the surface of the water as the wriggler rests at the surface. The wrigglers feed on bits of organic matter and microörganisms. The pupa has the head and thorax very remarkably enlarged, and there are two breathing tubes which project from the back of the

FIG. 352. Wing of a mosquito (*Mansonia titillans* Walk.) enlarged, showing scales on veins, and a portion of same further enlarged

(After Felt)

thorax. The pupa stage lasts from one to three days, the whole life from egg to adult requiring from eight days to two or three weeks. Not only are mosquitoes exceedingly annoying, rendering some sections almost uninhabitable, but it has been shown that malarial fever is transmitted only by mosquitoes of the genus *Anopheles*, and that the dreaded yellow fever is similarly carried only by species of the genus *Stegomyia*, which has resulted in an entire change in the methods of controlling these diseases. Very much can be

done toward the riddance of mosquitoes in thickly settled communities by destroying their breeding places by draining or filling the pools and by oiling the surface of small ponds, rain barrels, etc.

True midges (*Chironomidae*). Many of these look much like mosquitoes, the males having the plumose antennæ and being of about the same size, but the wing-veins are simpler and fewer in

FIG. 353. A midge (*Chironomus* sp.). (Greatly enlarged)
a, adult male; *b*, pupa; *c*, larva. (After Felt)

number, and lack the scales. Most of the larvæ are aquatic, being very long, threadlike worms which live in the slime and decaying vegetation at the bottom of pools and streams, where they feed on vegetable matter. Many are a bright red in color and have been called blood-worms. The minute punkies, or "no-see-ums," are among the worst enemies of the hunter and fisherman, and one must have a thick skin to withstand their bloodthirsty attacks.

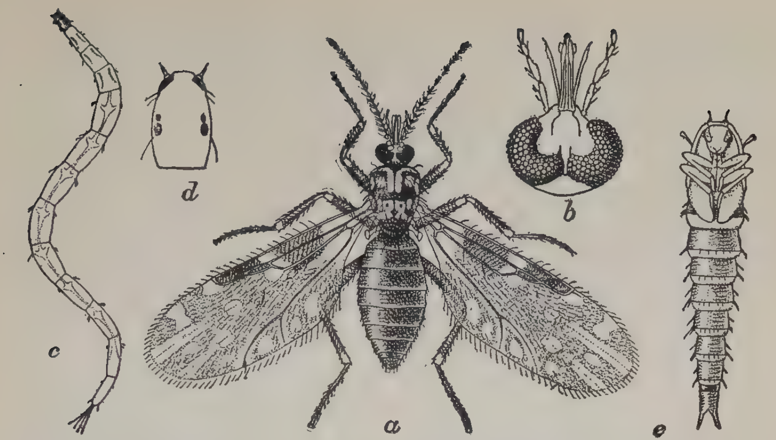

FIG. 354. A punkie, or "no-see-um" (*Ceratopogon guttipennis*). (Greatly enlarged) *a*, adult; *b*, head of same; *c*, larva; *d*, head of same; *e*, pupa. (After Pratt, United States Department of Agriculture)

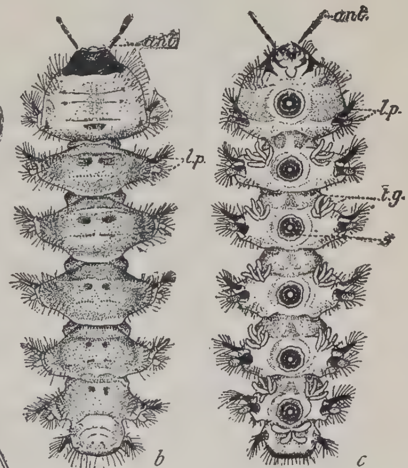

FIG. 355. *a*, a net-winged midge (*Bibliocephala elegantulus*), female (two and one half times natural length); *b*, *c*, upper and under sides of larva of *B. comstockii* (five times natural length)

(After Kellogg)

They are grayish-black, not over one twenty-fifth of an inch long, and the larvæ develop in the water in stumps and logs and under damp, dead bark.

The net-winged midges (*Blepharoceridae*) are so called on account of the peculiar network of small veins crossing the main wing-veins around the margin of the wing, which are peculiar to this family. The small, black larvæ live in masses on the rocks in swift-running mountain streams, and seem to have but seven segments strongly constricted at each joint.

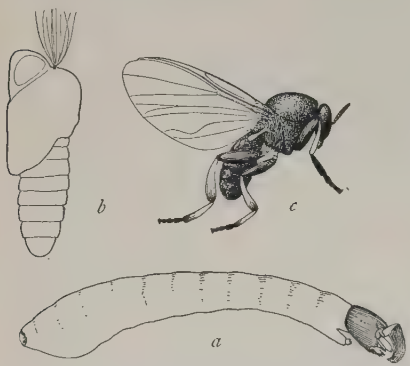

FIG. 356. A black fly (*Simulium venustum*). (Four times natural size)

a, larva; *b*, pupa; *c*, adult. (After Weed)

The Dixa-midges (*Dixidae*) include but a single genus, whose larvæ are also aquatic. Both of the last families comprise only a few uncommon species, and lack the whorls of hairs of the male antennæ.

The black-flies (*Simuliidae*). Another pest of mountain lovers is the black fly, the females of which are most bloodthirsty and often

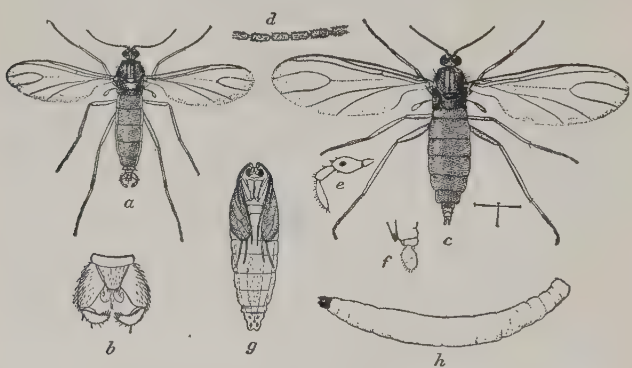

FIG. 357. The fickle midge (*Sciara inconstans*), a fungus-gnat sometimes troublesome in greenhouses. (Much enlarged)

a, male; *b*, genital organs of same; *c*, female; *d*, enlarged antennal segments of same; *e*, maxillary palpus of same; *f*, tip of abdomen of same from side; *g*, pupa; *h*, larva (After Chittenden, United States Department of Agriculture)

appear in immense numbers. The larvæ are found attached to rocks in shallow, swift-flowing streams, where they feed on various minute plants and bits of vegetation. The adult flies are about one fifth of an inch long, stout-bodied, blackish, with short legs and antennæ, though the antennæ have many distinct segments. Recent experiments made in the White Mountains indicate that it may be possible to eradicate the larvæ in mountain resort regions by oiling the streams with Phinotas oil. The southern buffalo gnat is a serious pest of domestic animals in the South, such immense swarms sometimes appearing as to cause their death.

Fig. 358. The pine-cone willow gall caused by a cecidomyiid, cut open at right to show maggots within

(After Washburn)

Fungus-gnats. Wherever there is decaying vegetable matter or damp fungi, as in decaying wood, under damp bark, in decomposing leaves, etc., there are found small, white or pink maggots, which develop into the graceful little fungus-gnats (*Mycetophilidae*). The larvæ often stick together in large patches, and sometimes form long processions of wriggling maggots. One species feeds on injured apples, while another has been shown to cause a form of potato scab, and one is a serious pest of mushrooms, but most of the larvæ are entirely harmless. The flies are mosquitolike in general form, but the antennæ are bare and the coxæ are unusually long.

FIG. 359. Pear midge (*Diplosis pyrivora*). (Enlarged)
(After Riley)

Gall-gnats. The smallest and most delicate of the gnatlike flies are the gall-gnats (*Cecidomyiidae*). The adults are rarely over one eighth of an inch long, with long antennæ clothed with short hairs, and with the wing-veins greatly reduced in number. They will be rarely noticed by the beginner, but the work of the larvæ is often much in evidence, owing to their feeding within the stems and leaves of plants and giving rise to galls. Frequently a green, cone-shaped gall is found on the tips of willow twigs, known as the pine-cone willow-gall, which is caused by one of these larvæ (*Cecidomyia strobiloides*). The larvæ of the clover-seed midge live in the heads of clover and destroy the seed so that in many sections it is often impossible to mature it. The best-known example of the family, and our worst wheat pest, is the Hessian fly, so called because it was supposedly introduced in straw brought over to Long Island by the Hessian troops during the Revolutionary War. The maggots live between the wheat stalk and the leaf, weakening the plant and seriously curtailing production where they are abundant.

FIG. 360. The Hessian fly, adult male. (Much enlarged)
(After Marlatt, United States Department of Agriculture)

SHORT-HORNED FLIES (*BRACHYCERA*)

In this section the antennæ are composed of from three to five segments, the families being divided into three groups according to the structure of the antennæ, and being further distinguished by the wing-venation.

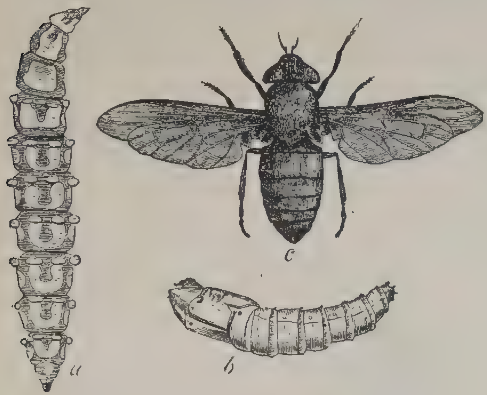

FIG. 361. Horse-fly (*Tabanus atratus*)
a, larva; *b*, pupa; *c*, adult. (After Riley)

In the first group the third segment of the antenna is clearly ringed, showing that it is made up of several segments grown together.

Horse-flies. The best-known family of this group is that of the horse-flies (*Tabanidae*). They are well-known pests of live stock and often become annoying to man. The adults have short, broad heads, large eyes, thick bodies, short, oval abdomens, and strong, powerful wings, which enable them to outstrip the swiftest horse. They are often most troublesome along wooded roads, where they will attack a horse in swarms and, with their loud buzzing, render the animal frantic. The larvæ are long, pointed maggots which live mostly in water in swampy places and along the edges of streams and ponds, and are carnivorous. In the swamp lands of southern Texas and Louisiana the large horse-flies appear in such swarms as to make life for cattle almost impossible, and along our coasts wherever

FIG. 362. A "green-head" (*Tabanus lineola* Fab.). (Much enlarged)
(After Lugger)

there is marshland the well-known green heads annoy bathers as well as animals. Our largest horse-fly is an inch long, with a two-inch wing expanse, and of a dull black color, while other common, smaller species are brown, with the wings banded with black. Only the females are bloodsuckers, the males feeding on the pollen of flowers.

The soldier-flies (*Stratiomyidae*) somewhat resemble the smaller horse-flies, and are so named on account of the bright yellow or green stripes across the abdomen. The antennæ are somewhat longer

FIG. 363. *Stratiomyia discalis.* (Greatly enlarged)
(After Lugger)

and the wing venation is quite characteristic. The adults are found on flowers near water, and the larvæ are carnivorous or feed on decaying vegetable matter, living in water, earth, or decaying wood.

In the second group are found two families having four or five distinct antennal segments, — the robber-flies (*Asilidae*) and the nearly related Midas-flies (*Midaidae*), which have very similar habits.

The robber-flies (*Asilidae*). They are well named, being large, hairy, ferocious-looking flies, which are strong, swift flyers. They may often be seen resting quietly on a dead twig, which they closely resemble in color; suddenly they will dart off and in mid-air will snatch a fly or any insect which they can overpower, in much the

same manner as does a dragon-fly. The most common species are of a sober gray color, marked with white, yellow, or black, with a long, tapering abdomen, long, narrow wings, large, keen eyes, and a strong proboscis, with which they suck the juices of their prey. Other species are thickly clothed with black and yellow hairs, so that they closely resemble bumble-bees. The larvæ are mostly predacious and live in the ground or in decaying wood, where they feed on the larvæ of beetles and on decaying vegetable matter. The robber-flies can hardly be considered beneficial, as they rarely feed on noxious insects to any extent, and often destroy bees.

FIG. 364. A robber-fly (*Stenopogon inquinatus*), and another (*Dasyllis sacrata*) resembling a bumble-bee. (Natural size)

(After Kellogg)

In the third group is a considerable series of important families, in which the first two segments of the antennæ are small and the third is large and clublike and bears a single, conspicuous bristle, called an *arista*.

The bee-flies (*Bombyliidae*) are medium-sized, oval-shaped flies, with a thick covering of yellow hairs, giving them a resemblance to bees which is increased by their habit of hovering over flowers, upon the nectar of which the flies feed by means of their long tongues. Some of them frequent orchards and aid in carrying the pollen from flower to flower by means of the body hairs, to which it adheres. The larvæ live in the ground and are very beneficial, being parasitic upon cutworms, army-worms, and grasshopper eggs.

FIG. 365. A bee-fly (*Bombylius* sp.). (Enlarged)

(After Weed)

The long-legged flies (*Dolichopodidae*) should be mentioned, for they are of such a striking metallic green, or blue, as to attract

attention as they flit over rank-growing foliage in damp places. The adults feed on small flies, and the larvæ live underground, being either predacious or feeding on decaying vegetable matter.

FIG. 366. A long-legged fly (*Psilopodinus sipho*)
(After Lugger)

The wasp-flies (*Conopidae*) should also be mentioned, on account of their close resemblance to wasps, with which they may readily be confused at first glance, and which they undoubtedly mimic. They are narrow-waisted, the tip of the abdomen is like that of a wasp, and they are often banded and colored to heighten the likeness. The head is robust, which has given them the common name of "thick-headed flies." The larvæ are parasitic within the bodies of wasps, bumble-bees, and grasshoppers, on which the eggs are laid. The adults feed on nectar and pollen of flowers, over which they may be found hovering.

FIG. 367. A wasplike fly (*Physocephala affinis*). (One and one half times natural size)
(After Kellogg)

The flower-flies (*Syrphidae*) are medium-to-large-sized, bright-colored flies which feed upon nectar and pollen of flowers, over which they may be seen to hover, almost motionless, for several seconds and then to dart off and as quickly return. These flies may be readily recognized by a thickening which looks like a vein extending across the middle of the wing. Our more common species of the genus *Syrphus* have the abdomen marked with alternate bands of black and yellow, and have greenish, bronze, or yellowish bodies. They lay their small, oval, white eggs

FIG. 368. The bee-fly (*Eristalis tenax*). (Natural size)

among colonies of plant-lice, around which the flies may be seen hovering, and the maggots devour the aphides greedily, being among their most important natural enemies. Some of the larger species are thickly covered with yellow and black hairs, thus closely resembling bumble-bees, in whose nests their larvæ reside. A common species which is often found on windows in fall is known as the drone-fly, from its close resemblance to a honey-bee drone. Its larva lives in foul water and excrement, and is typical of a group which is often found in privies and similar filth. The larva is maggotlike in shape but has a long, extensile tube, through which it breathes, projecting from the tip of the abdomen to the surface of the food-material, which has given it the name of "rat-tailed maggot." None of the family seems to be injurious, and those larvæ which feed on plant-lice are exceedingly beneficial.

FIG. 369. Rat-tailed maggot, larva of a syrphid fly similar to Fig. 368. (Twice natural size)

(After Kellogg)

Bot-flies (*Oestridae*). Another family in which the flies are well covered with hairs, so as to closely resemble bees, is that of the bot-flies, whose maggots are among the worst insect parasites of domestic animals. The adults have very rudimentary mouth-parts, so that they probably take no food. The eggs are usually laid on the hair of various animals, from which they are licked off and pass into the alimentary tract, though others lay them upon the lips or in the nostrils of the host. Among the more common are the horse bot-fly, which gives rise to the bots in the stomach of the horse, the ox-warble fly, whose maggots pass from the stomach through the tissues of cattle and finally emerge through holes in the skin, causing "grubby" hides, and the sheep bot-fly,

FIG. 370. A syrphus-fly (*Volucella evecta*) which resembles a bumble-bee and is an inquiline in bumble-bees' nests (after S. J. Hunter); and a typical syrphus-fly (*Syrphus ribesii*)

whose maggots work in the nasal sinuses of sheep, causing "grub-in-the-head," which often results in fatal vertigo, or "staggers." Other species affect various wild mammals, one inhabiting rabbits being particularly common in the South. When full grown, the bots pass out with the excreta, or drop to the ground, in which they pupate.

FIG. 371. The ox bot-fly (*Hypoderma lineata*)

(After Marlatt, United States Department of Agriculture)

The muscids. The last group of the typical flies is much the largest and is now held by most students of this order to represent from twenty to thirty families, so that it may be considered as a superfamily. They are all commonly called muscids (superfamily *Muscina*) and the house-fly is the best-known example. No attempt will be made to give the technical distinctions by which the different families or subfamilies may be distinguished, for the knowledge of an expert is required for their recognition; but the different groups will be considered according

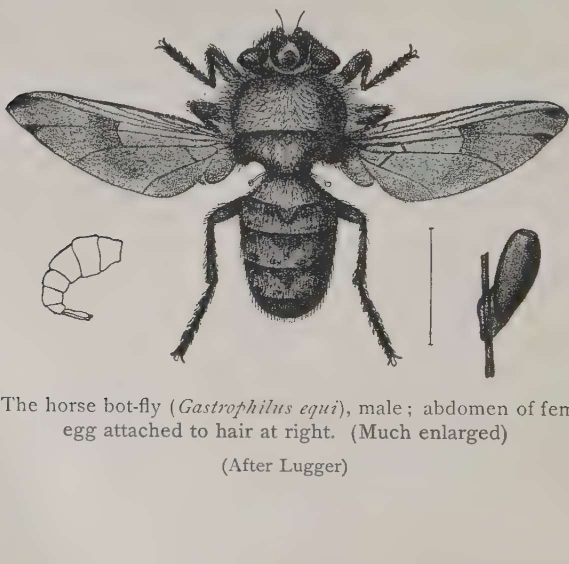

FIG. 372. The horse bot-fly (*Gastrophilus equi*), male; abdomen of female at left; egg attached to hair at right. (Much enlarged)

(After Lugger)

FIG. 373. Bots in stomach of a horse; some removed to show point of attachment (After Osborn, United States Department of Agriculture)

to their habits. All are alike in having three-segmented antennæ bearing a strong bristle near the base, the modifications of which aid in distinguishing the groups. The larvæ are typical white or light-colored maggots living within their food, and the puparia are usually formed on or in the soil.

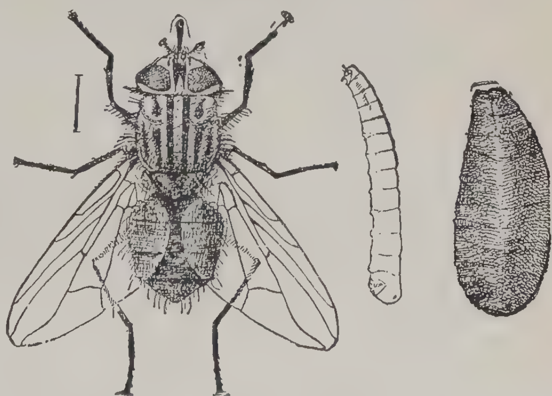

FIG. 374. Stable-fly (*Stomoxys calcitrans*), adult, larva, and puparium. (Enlarged)

(After Howard, United States Department of Agriculture)

The discovery in recent years that the common house-fly and also many of its near relatives are responsible for the spread of typhoid fever, intestinal diseases of infants, and possibly other infectious diseases has given new interest to the study of the common flies heretofore considered mere

nuisances. Very similar and almost indistinguishable from the house-fly is the common stable-fly, so annoying to cattle. The mouth-parts of the females are fitted for piercing. Just before a storm these flies frequently come into houses and annoy us, from which comes the saying that flies bite before a storm. Like those of the housefly, the larvæ live in fresh horse manure. The little horn-flies often annoy cattle by assembling on their flanks and clustering at the base of the horns. The maggots develop in cow manure.

The flesh-flies (*Sarcophagidae*) are so called because many of them lay their eggs on the bodies of dead animals or in open wounds,

FIG. 375. The horn-fly. (Enlarged)
a, egg; *b*, fly; *c* and *d*, head and mouth-parts. (After J. B. Smith)

though some of the larvæ live in dung and decaying vegetable matter. The common flesh-fly (*Sarcophaga sarracenia*) looks like a very large house-fly and gives birth to live maggots (the eggs hatching in the body of the female), which are deposited on fresh meat or in open wounds. The blow-flies and blue-bottle flies are about the size of house-flies, with the abdomen steely-blue or greenish, and lay their eggs on meat, cheese, or other provisions, which are said to be "blown." The eggs hatch in a day; the maggots feed on the juices of decaying meat and become full grown in a few days. The common blue-bottle or green-bottle fly (*Lucilia caesar*) also lays its eggs on cow dung. The screw-worm fly (*Lucilia macellaria*) is of a bright, metallic green, about a third of an inch

long, with four black stripes on the thorax. It is one of the most serious pests of cattle in the South and West, laying its eggs in wounds or sores in which the maggots develop, causing very serious festering sores. Sometimes it oviposits in human nostrils, the work of the larvæ not infrequently resulting fatally.

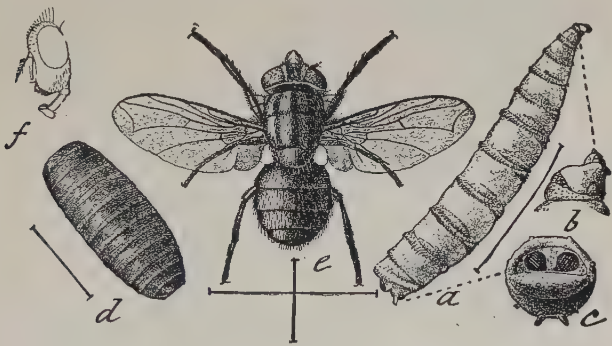

FIG. 376. The screw-worm fly (*Lucilia macellaria*)

a, *b*, *c*, larva and details of same; *d*, pupa; *e*, adult; *f*, head from side. (After J. B. Smith)

The tachina-flies (***Tachinidae***) are found frequenting flowers; they somewhat resemble the last group, but are commonly recognized by the numerous stout bristles and hairs with which they are clothed. The adults are mostly of a modest gray color, with thorax streaked with blackish-brown or gray, though some have yellow-banded or red abdomens. The eggs are laid on the bodies of caterpillars or on foliage on which they are feeding, and the maggots are parasitic within them. Any one who has tried rearing moths from their caterpillars will have encountered these flies, for often a score or more will inhabit a large caterpillar. When full grown the puparia are formed within the caterpillar or pupa, which never transforms. Some European species which are parasitic on the gypsy moth have been imported into Massachusetts with the hope that they may aid in controlling that pest in this country.

FIG. 377. A parasitic tachina-fly and its puparium

(After Weed)

The tachina-flies are among our most beneficial insects, their white eggs being commonly found on the necks of caterpillars and grasshoppers, the flies appearing in large numbers whenever there is an outbreak of such caterpillars as the army-worm.

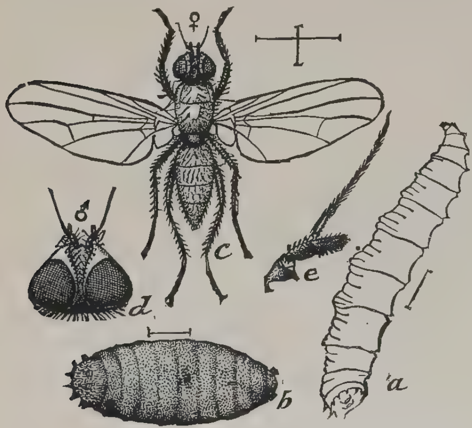

FIG. 378. The cabbage-maggot. (Enlarged)

a, larva; *b*, pupa; *c*, adult; *d*, head; *e*, antenna. (After Riley)

Root-maggot flies (*Anthomyiidae*) are another group of troublesome flies belonging to this series, many of whose larvæ are serious pests of the roots of vegetables. The flies somewhat resemble house-flies, but are smaller and slighter in build. The cabbage-maggot and onion-maggot are well-known examples of these injurious larvæ, and wherever small flies are seen hovering around these or other root crops, such as radishes, turnips, beets, etc.,

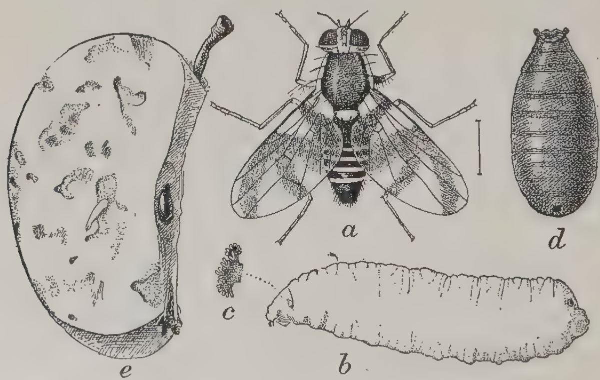

FIG. 379. The apple-maggot

a, adult; *b*, larva, or maggot; *c*, funnel of spiracle on head; *d*, puparium; *e*, portion of apple showing injury by maggots. (*a*, *b*, *d*, enlarged; *e*, reduced.) (After Quaintance, United States Department of Agriculture)

they may well be regarded with suspicion. One species occasionally attacks the roots of corn, and another, the beet leaf-miner, makes tortuous mines in beet leaves.

The fruit-flies (*Trypetidae*) burrow in the flesh of fruits and in the stems of plants. The common round gall on the golden-rod is caused by the maggot of one of this group, most of which are medium-sized flies, often metallic in color and usually with strikingly banded or mottled wings. In New England the common apple-maggot (*Rhagoletis pomonella*), or "railroad worm," which

FIG. 380. A pomace-fly (*Drosophila ampelophila*). (Enlarged)

a, adult; *b*, antenna of same; *c*, base of tibia and first tarsal segment; *d*, *e*, puparium from side and above; *f*, larva; *g*, anal spiracles of same. (After Howard, United States Department of Agriculture)

bores through the flesh of the apples, is a well-known example, the adult being black and white with black-banded wings. In Mexico a similar species infests the orange and is occasionally imported into this country. The little pomace-flies (*Drosophila* sp.), small, yellowish flies about one eighth of an inch long, are common about cider mills and wherever there is decaying fruit, in which their maggots develop.

II. PUPIPARA

This suborder includes three parasitic families, with but few species, so named on account of the peculiar mode of reproduction. The eggs and larvæ are developed within the body of the female and are given birth when mature and all ready to pupate.

Some of the louse-flies (*Hippoboscidae*) are winged, though some of them cast off or bite off their wings, and are frequently found on birds of prey, while others are common on various birds and mammals. The bodies are very much flattened, the head is joined to the thorax broadly, the antennæ consist of a single segment, and the wing-venation is very simple. The best-known example of the wingless forms is the common sheep-tick (*Melophagus ovinus*), which should be carefully distinguished from the true ticks (belonging to the Arachnida), and which is the only troublesome member of the family.

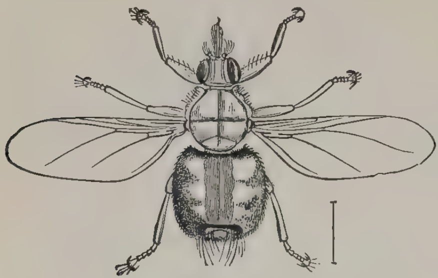

FIG. 381. A louse-fly (*Olfersia* sp.). (Enlarged)

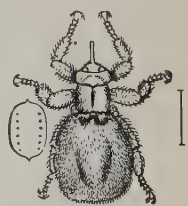

FIG. 382. Sheep-tick (*Melophagus ovinus*)

A nearly related family (*Nycteribiidae*), looking like small spiders, are known as bat-ticks and are even more degenerate in structure. The third family (*Braulidae*) consists of a single species, the bee-louse, a minute insect about one sixteenth of an inch long, which is found clinging to the thorax of queen and drone bees.

FIG. 383. Bee-louse (*Braula caeca*) and its larva. (Greatly enlarged)

FLEAS (*SIPHONAPTERA*)

The fleas may be considered in connection with the flies, for they were formerly thought to be wingless Diptera, but are now classed as a distinct order. The name of the order is derived from two Greek words, *siphon* (a tube) and *apteros* (wingless), referring to the tubelike mouth-parts and the lack of wings. The fleas have an oval body which is very strongly compressed laterally, enabling them to pass through narrow cracks. They are usually of a brown color, with small heads bearing sucking or piercing mouth-parts, and

have the merest rudiments of wing-pads. The posterior legs are strongly developed, so that they are able to jump a considerable distance. In the adult stage they live upon various warm-blooded animals, sucking their blood. The eggs are scattered about in the sleeping places of domestic animals and in the cracks of floors. The larvæ are wormlike creatures, with a distinct head, but without legs. They have biting mouth-parts, and feed upon particles of decaying animal and vegetable matter always abundant in the places in which they live. The full-grown larva spins a cocoon in which the pupal stage is passed. In view of these habits, in addition to cleansing domestic animals it is also necessary to thoroughly clean the sleeping places of cats and dogs, to scrub the floors, and to treat large cracks, in which rubbish may accumulate, with gasoline, kerosene, or a similar contact insecticide. In temperate climates the common species which lives upon dogs and cats is the only one often troublesome to human beings; in the tropics fleas are much more abundant, and attack man as well as the domestic animals.

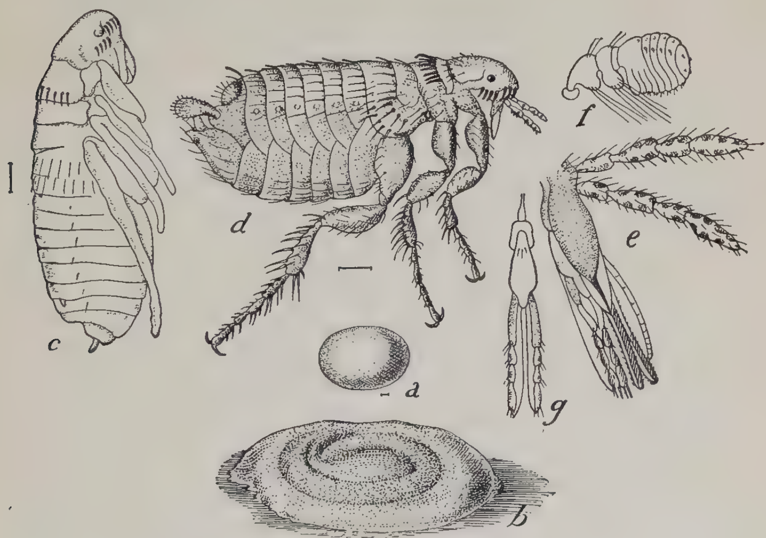

FIG. 384. Cat and dog flea (*Ctenocephalus canis*). (Much enlarged)

a, egg; *b*, larva in cocoon; *c*, pupa; *d*, adult; *e*, mouth-parts from side; *f*, antenna; *g*, labium from below. (After Howard, United States Department of Agriculture)

Summary of the Diptera

Suborder I. Typical Diptera (*Diptera genuina*).

Section 1. Antennæ with over five segments. Long-horned Diptera (*Nematocera*).

Aquatic larvæ.

Families. Mosquitoes (*Culicidae*).
Midges (*Chironomidae*, etc.).
Black-flies (*Simuliidae*).

Nonaquatic larvæ.

Families. Crane-flies (*Tipulidae*).
Fungus-gnats (*Mycetophilidae*).
Gall-gnats (*Cecidomyiidae*).

Section 2. Antennæ with five or less segments. Short-horned Diptera (*Brachycera*).

Third antennal segment ringed.

Families. Horse-flies (*Tabanidae*).
Soldier-flies (*Stratiomyidae*).

Antennæ with four or five segments.

Families. Robber-flies (*Asilidae*).
Midas-flies (*Midaidae*).

Antennæ with three segments; with an arista on third segment.

Families. Bee-flies (*Bombyliidae*).
Flower-flies (*Syrphidae*).
Wasp-flies (*Conopidae*).
Bot-flies (*Oestridae*).

Superfamily. Muscids (*Muscina*).
House-flies, etc. (*Muscidae*).
Flesh-flies (*Sarcophagidae*).
Root-maggot flies (*Anthomyiidae*).
Tachina-flies (*Tachinidae*).
Fruit-flies (*Trypetidae*).

Suborder II. Pupipara.

Families. Louse-flies (*Hippoboscidae*).
Bat-ticks (*Nycteribiidae*).
Bee-lice (*Braulidae*).

CHAPTER XV

THE SAW-FLIES, ICHNEUMONS, WASPS, BEES, AND ANTS (*HYMENOPTERA*)

Characteristics. Insects with four membranous wings, with few cross-veins, the hind-wings smaller than the fore-wings; mouth-parts, formed for both biting and sucking, or lapping; abdomen of the females, usually bearing an ovipositor or sting; metamorphosis, complete.

The insects of this order are mostly beneficial, though a few families are injurious to crops. Probably no other invertebrate animals, and very few vertebrates, have as highly developed instincts as many of the insects of this order, the social ants, bees, and wasps having always been the objects of the greatest popular and biological interest on account of their high intelligence, if it may be so termed.

The wings are membranous, with but few veins, are frequently clothed with short hairs, and are held together by a row of hooks on the anterior margin of the hind-wings, which grasp a fold of the hind-margin of the fore-wings, so that the two wings move together as one. The name of the order is derived from *hymen* (a membrane) and *pteron* (a wing). The mandibles are always well developed and used for biting. In the ants, bees, and wasps the maxillæ are more or less developed as a sheath surrounding the labium, which is prolonged into a tongue, so that these mouth-parts are adapted for sucking or lapping the liquid food.

Most of the larvæ are footless and maggotlike, living within the food, where the eggs are placed by the adults, but the larvæ of the first two families bear both true legs and several pairs of abdominal prolegs, and resemble caterpillars in both form and habits. Many species spin a cocoon before pupating, and the newly formed pupæ are white, with the legs, wings, and antennæ pressed close to the body.

The different families fall into several natural groups recognizable by their structure and habits.

Suborder I. The Boring Hymenoptera (*Terebrantia*)

In the first suborder the females bear a well-developed ovipositor, with which the eggs are inserted into the food plant or host insect, and the trochanters of the hind-legs consist of two segments.

1. PLANT-EATING HYMENOPTERA

The first two families are distinguishable by the base of the abdomen being broadly joined to the thorax, with no constriction at this point.

The saw-flies (*Tenthredinidae*) are so called on account of the saw-like ovipositor. It is toothed at the tip, having a structure which enables the females to insert their eggs beneath the surface of leaves

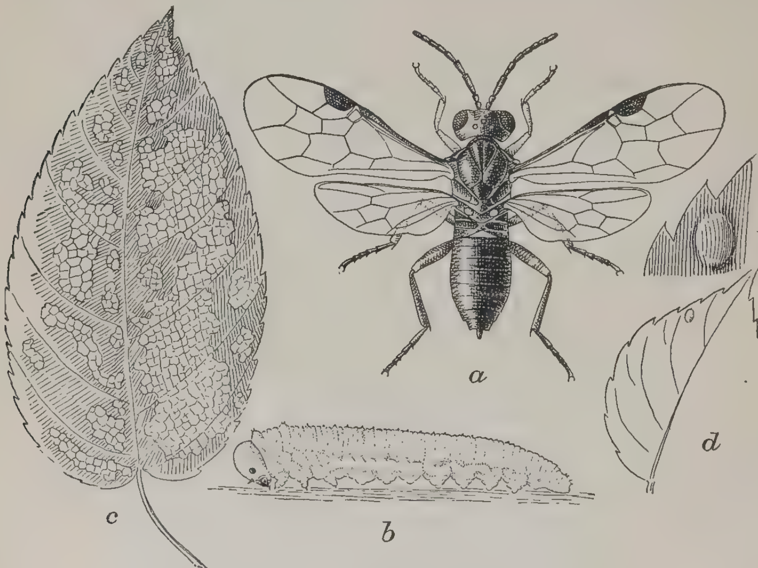

Fig. 385. The American rose-slug (*Endelomyia rosae*)

a, adult saw-fly; *b*, mature larva; *c*, work of larva on rose leaf; *d*, piece of rose leaf showing location of egg near margin; *e*, egg. (*a*, *b*, *c*, and *e* enlarged, *d*, natural size.) (After Chittenden, United States Department of Agriculture)

or in the stems of plants. They are medium-sized insects from one fourth to one half of an inch long, usually blackish or yellow-and-black in color, with the wings folded over the back when at rest. The larvæ resemble small caterpillars, but usually have a larger

number of prolegs on the abdomen, and lack the hard shield usually found on the prothorax of lepidopterous caterpillars. Most of them feed on foliage, and many are quite injurious. Several species are soft-bodied and covered with a viscid, slimy matter, which has given them the name of "slugs." Among the more common species are the yellow-and-green currant worms (*Nematus ribesii*), which devour the foliage of currants and gooseberries, the rose-slug (*Endelomyia rosae*), which strips off the surface of rose leaves, leaving them brown as if scorched, and the pear-slug (*Eriocampa cerasi*), which injures pear and cherry foliage in the same manner. Other species often defoliate strawberry and raspberry bushes, and there are numerous species which may be found on various shade and forest trees, one of the most injurious being the larch saw-fly (*Lygaeonematus erichsonii*), which has defoliated and thus destroyed large areas of larch in New England and Canada.

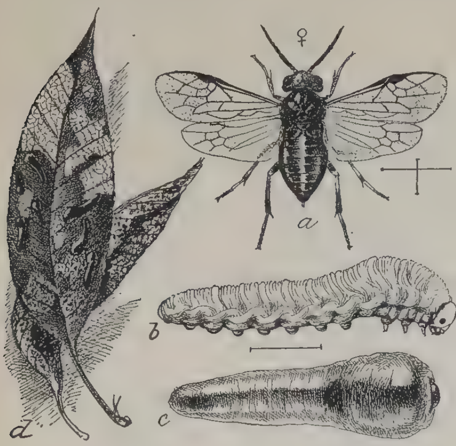

FIG. 386. The pear-slug

a, adult saw-fly, female; *b*, larva with slime removed; *c*, same in normal state; *d*, leaves with larva (natural size). (*a*, *b*, *c*, much enlarged.) (After Marlatt, United States Department of Agriculture)

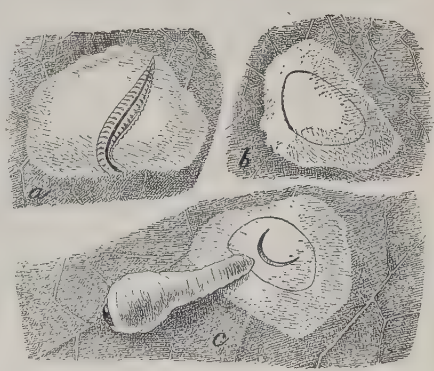

FIG. 387. Pear-slug, illustrating method of oviposition and emergence of larva. (Enlarged)

a, cutting of cell beneath epidermis of leaf, showing the tip of the ovipositor; *b*, the cell after the egg has been deposited; *c*, same after the escape of the larva. (After Marlatt, United States Department of Agriculture)

Horn-tails (*Siricidae*). The ovipositor of the horn-tails is cylindrical, more like a borer, and, as it projects from the abdomen, has given the family its name. The eggs are laid within the stems of grasses and various plants, such as berry canes and alder, while some of the larger species deposit them in the solid wood of various shade and forest trees, usually when the tree is beginning to die.

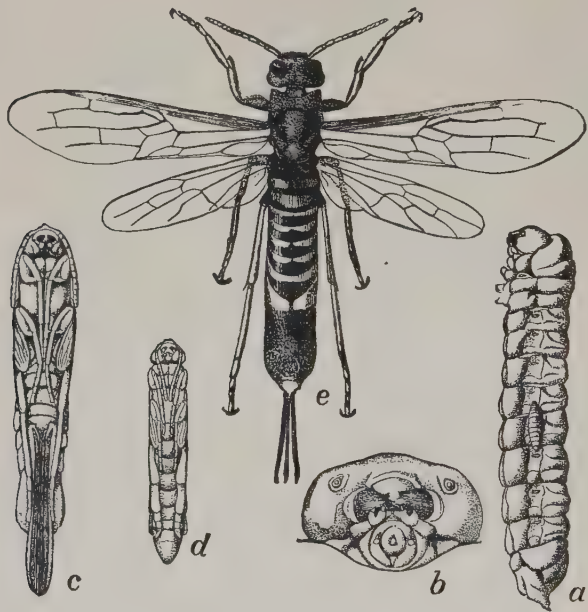

FIG. 388. The pigeon tremex, or horn-tail (*Tremex columba*)

a, larva with young larva of *Thalessa* fastened to its side; *b*, its head; *c*, *d*, female and male pupæ; *e*, female. (After Riley)

The larvæ feed within these plants, tunneling out burrows, and are difficult to combat. Fortunately but few are of considerable economic importance.

2. GALL-INHABITING HYMENOPTERA

Gall-flies (*Cynipidae*). The gall-flies lay their eggs in the leaves and stems of plants, and the injury done by the developing larvæ causes the formation of a characteristic gall by the plant tissues surrounding them. The adults are small insects resembling wasps,

and the abdomen is joined to the thorax by a slender petiole, or stalk, as in the families named below, from which they are distinguished by lacking the dark spot, or stigma, toward the end of the anterior margin of the fore-wings. They have short, thick bodies, and the abdomen is commonly compressed, so that the segments appear to be more or less telescoped. The mossy rose-gall (*Rhodites rosae*), which forms a large, mosslike gall on the stems of roses, and the spongy oak-apple (*Amphibolips spongifica*), which looks like a puff-ball on the leaves and stems of oaks, are well-known examples. The adult flies may be easily reared by removing the galls from the plants when fully matured and placing them in any suitable receptacles. Only a few species are of economic importance on cultivated crops, among which may be mentioned the pithy blackberry-gall (*Diastrophus nebulosus*), an irregular swelling two to three inches long on blackberry stems, inside which will be found numerous larvæ.

FIG. 389. Mossy rose-gall (*Rhodites rosae*)
(After Comstock)

FIG. 390. Spongy oak-apple (*Amphibolips spongifica*)
(Photograph by Weed)

3. PARASITIC HYMENOPTERA

Most of the small, slender, wasplike hymenoptera, which are distinguishable from the true wasps by the two-segmented trochanters of the

hind legs, are parasitic upon the eggs or larvæ of other insects, and belong to a group of families which are the most important of parasitic insects. The technical differences between the more common families are based

FIG. 391. A gall-fly (*Cynips quercussaltratix*), which produces the jumping galls formed on oak leaves. (Much enlarged)

(After Kellogg)

FIG. 392. Long-tailed ophion (*Ophion macrurum*). (Much enlarged)

(After Riley)

upon the wing-venation, and need not be discussed, but the general habits are somewhat similar. The female lays her eggs either

FIG. 393. *Pimpla conquisitor.* (Twice natural size)

a, female; *b*, female in act of ovipositing in cocoon of tent caterpillar. (After Fiske)

upon or within a larva or an egg, the larger forms laying but a single egg on a larva, while the smaller species may deposit a considerable number within a large caterpillar. The young larva at once enters the body of the host and feeds upon its blood, not interfering with the principal tissues and organs, so that the host goes on growing and furnishing food to the parasite. Finally, however, the parasite so depletes the vitality of the host that it dies, though often not until it has transformed to a pupa. The parasitic larva then spins its cocoon, usually either within or upon the dead host, and in due time the adult parasite emerges and continues the good work. To a certain extent many parasites are peculiar to certain host insects, though many of them attack various larvæ or caterpillars having similar habits. Frequently many of our worst insect pests are brought under control by the beneficent work of these little parasites,

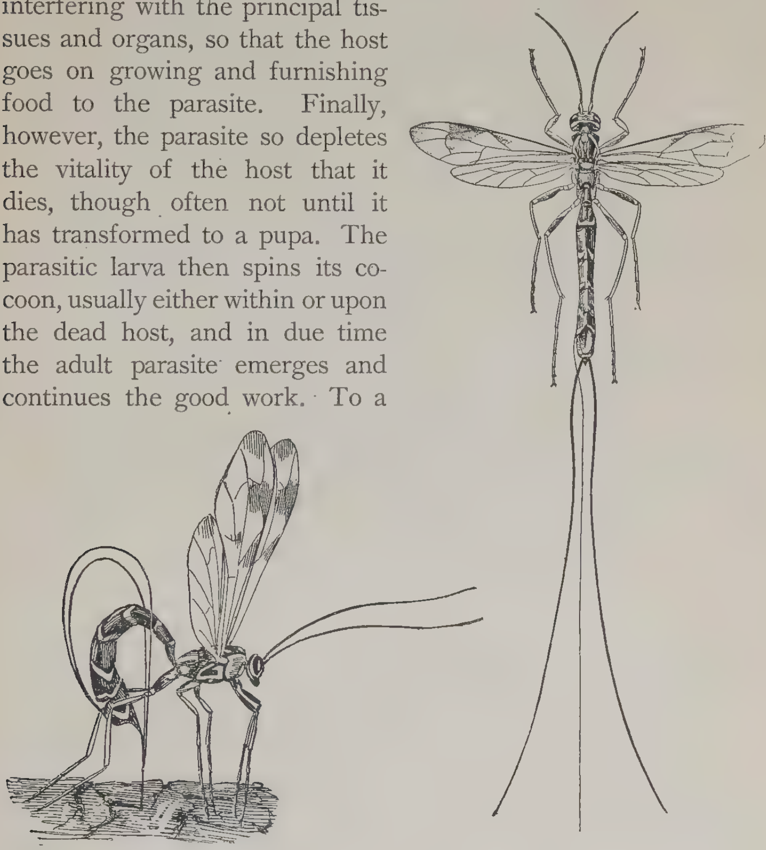

FIG. 394. Long-tailed ichneumon-fly (*Thalessa lunator*). (Natural size)

The parts of the long ovipositor normally lie together as a single organ; the figure at the left shows the manner of inserting the ovipositor in wood. (After Comstock)

and we are just commencing to learn how to utilize them in combating imported insects. Thus the state of Massachusetts and the United States Bureau of Entomology are now carrying on extensive experiments in the importation of the parasites of the gypsy and brown-tail moths, which are very largely effective in holding those insects in control in Europe. The various parasites which attack the eggs and caterpillars at different stages of growth have been imported; they are reared in this country until sufficiently numerous, and are then liberated in sections badly affected by the caterpillars, with the hope that they will ultimately become numerous enough to hold their hosts in check.

Ichneumon-flies (*Ichneumonidae*). Any one who has attempted to rear any of our large moths, such as the cecropia or polyphemus moths (see page 215), will have become acquainted with the *Ophion* flies, which commonly parasitize them. They are light brown or golden in color, about three fourths of an inch long, and the abdomen is compressed laterally, so that the back is ridged. A single egg is laid on the caterpillar, which lives to pupate. The *Ophion* larva spins a tough brown cocoon within the pupal shell and emerges from it the next spring. They belong to the large family of ichneumon-flies, which includes most of the larger parasites, though some of this family are quite small. The *Pimpla* flies are nearly the same size, but are black in color and have the abdomen more broadly joined to the thorax. They are effective parasites of many of our most common caterpillars, such as the tent caterpillar, tussock-moth caterpillars, the cotton-worm, and others.

FIG. 395. *Limneria fugitiva*, a parasite of the tent caterpillar. (Twice natural size)

(After Fiske)

Braconid-flies (*Braconidae*). Wherever plant-lice are abundant there will be found some empty brown skins, globular in form and with a small round hole in each. Other individuals will be brown, swollen, and dying as a result of the parasitism of little braconid flies which are developing within them. When mature the parasite

leaves the swollen skin of the aphis through a round hole. Often whole colonies of aphides will be found to have been thus parasitized. One little species (*Lysiphlebus tritici*) has been principally responsible for subjugating the green-bug, or southern grain aphis,

FIG. 396. *Lysiphlebus tritici*, male, the wasplike parasite of the green-bug. (Very much enlarged)

(After S. J. Hunter)

which has been so destructive to grain in the southwest; this parasite also attacks many other commonly injurious aphides. Larvæ of the large green tobacco or tomato worm (*Phlegethontius quinquemaculata* (Fig. 333) are frequently found covered with what appear to be small silken eggs. These are the cocoons of little braconids of the genus *Apanteles* which have developed within the caterpillar's body. Not

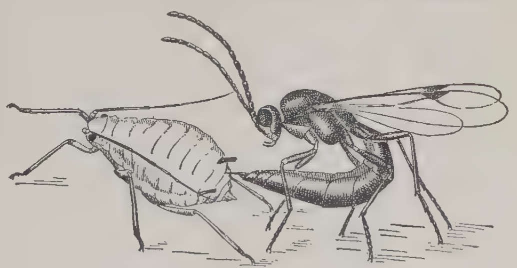

FIG. 397. *Lysiphlebus* parasite in act of depositing eggs in the body of a grain aphis. (Much enlarged)

(After Webster, United States Department of Agriculture)

infrequently such caterpillars are ruthlessly destroyed on the supposition that these are the eggs of the caterpillars, whereas they are its worst enemies and should always be protected. The braconids are small, wasplike flies, from one sixteenth to one eighth of an inch long, of brown or yellow-and-black colors.

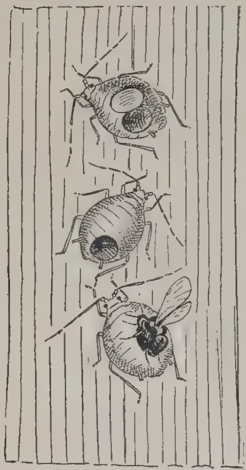

FIG. 398. Dead greenbugs, showing holes from which parasites emerge. (Much enlarged)

The upper figure shows the lid still attached, and the lower shows the parasite emerging. (After Webster, United States Department of Agriculture)

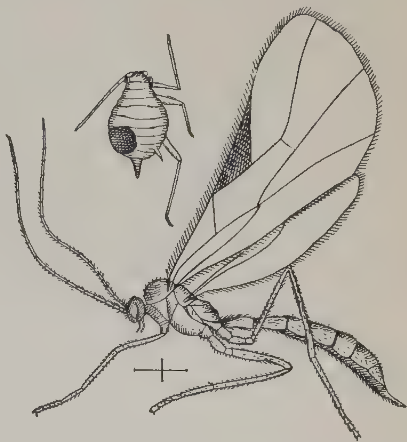

FIG. 399. Wheat-louse parasite (*Aphidius granariaphis* Cook) and parasitized aphid from which a parasite has emerged. (Much enlarged)

(Copied from J. B. Smith)

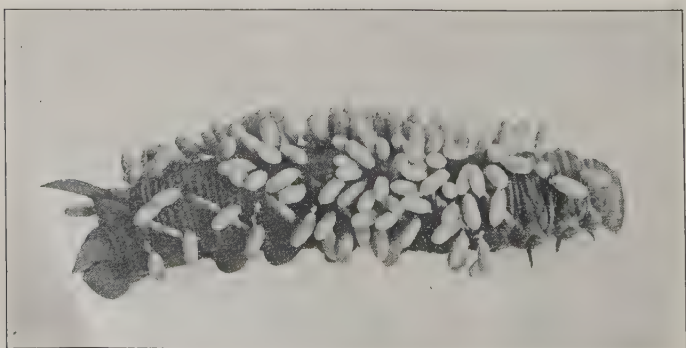

FIG. 400. Sphinx caterpillar with cocoons of braconid parasites

The chalcis-flies (*Chalcididae*) are even smaller, and are usually blackish with strongly metallic reflections of bronze or green, and are readily recognized by the stout bodies and the almost entire absence of wing veins. Some of them are parasitic on various caterpillars. One species (*Pteromalus puparum*) attacks the common

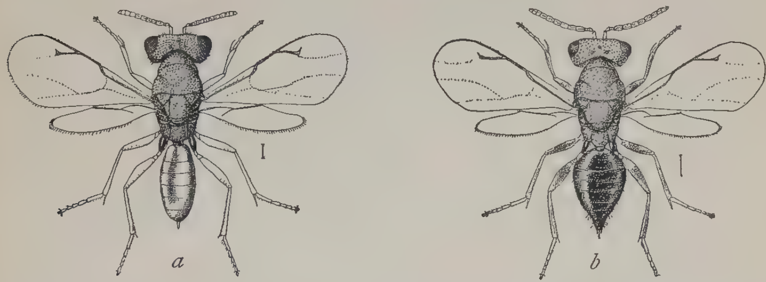

FIG. 401. *Pteromalus puparum*, a chalcis-fly which parasitizes the cabbage-worm and many other injurious insects. (Greatly enlarged, hair line shows natural size) *a*, male; *b*, female. (After Chittenden, United States Department of Agriculture)

cabbage-butterfly caterpillars, from one of whose chrysalids several hundred of the parasitic flies may often be reared, and in some sections entirely prevents the increase of this troublesome garden pest. Many of the species are parasitic in the eggs of insects, while others are the most effective parasites of scale insects. Unfortunately one or two species are injurious to crops, the best-known example being the joint-worm of wheat (*Isosoma tritici*), whose larva works in the lower stems, causing gall-like swellings of the joints and weakening them so that the grain is blown over, much the same as when affected by the Hessian fly.

FIG. 402. A chalcis parasite (*Chiropachys colon*) of the fruit-tree bark beetle

Smallest of all the parasites are the little proctotrypids (*Proctotrypidae*), the largest of which are

not over one twenty-fifth of an inch long, and the smallest not over one fifth that size. Most of them inhabit the eggs of insects, though some are secondary parasites; that is, they are parasitic on larger parasites, and thus are sometimes injurious.

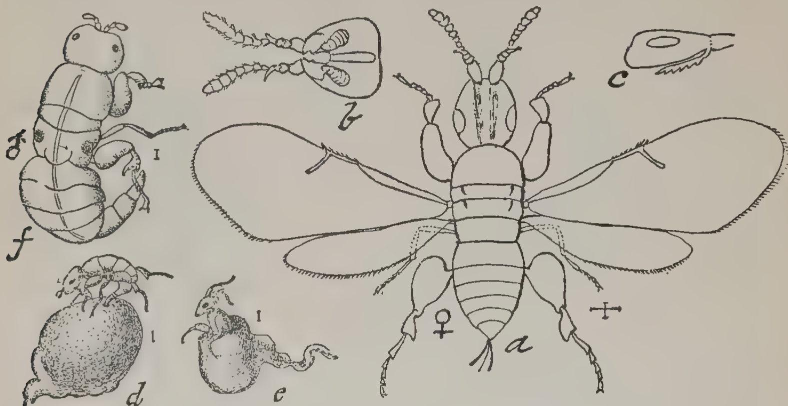

FIG. 403. The fig insect (*Blastophaga grossorum*), whose introduction has made Smyrna fig culture possible in California. (Enlarged)

a, adult female; *b*, head of same from below; *c*, from side; *d*, male fertilizing female; *e*, female issuing from gall; *f*, adult male. (After Westwood, from Howard)

SUBORDER II. THE STINGING HYMENOPTERA (*ACULEATA*)

In the second suborder the female bears a well-developed sting at the tip of the abdomen, which is effectively used as an organ of offense. The trochanters of the hind-legs have but a single segment in all of the ants, wasps, and bees which form this suborder.

1. THE ANTS (*FORMICINA*)

A long chapter might well be devoted to these well-known insects, for many interesting volumes have been written by some of our greatest naturalists concerning their remarkable intelligence and the highly developed organization of their society.[1] Every one recognizes an ant, but the so-called white ants, or termites (*Termitidae*, order *Platyptera*), and the velvet ants (*Mutillidae*) may be distinguished from them by the fact that the first segment of the

[1] See the most interesting monograph of Dr. W. M. Wheeler, "Ants," Columbia Biological Series.

abdomen of true ants forms a sort of knot or tooth between the thorax and abdomen. The males and females are winged and mate in their nuptial flight, which may often be observed on a warm summer day, when the air will be filled with them. After this the males soon die, but the females bite off their wings and either found a new colony or are taken in by some workers. The workers, or neuters, are wingless, undeveloped females. They may upon necessity lay eggs, but these give rise to males only. The workers do all the work of the colony, caring for the eggs and larvæ, which they feed and bring up with all the nicety of the best-ordered nursery. The true females, or so-called queens, merely lay the eggs, having no control over the colony, which is managed on the most socialistic lines by the workers. There are frequently many different sizes and forms of workers, each of which has a particular sort of work. Thus the large-headed, strong-jawed individuals are naturally the soldiers, while others look after the larvæ and eggs. Ants feed on various animal substances, being very fond of dead insects and sweets of all kinds. It is the latter taste which leads many species to take such care of the little green plant-lice (see page 127), which give off the sweet honey-dew of which

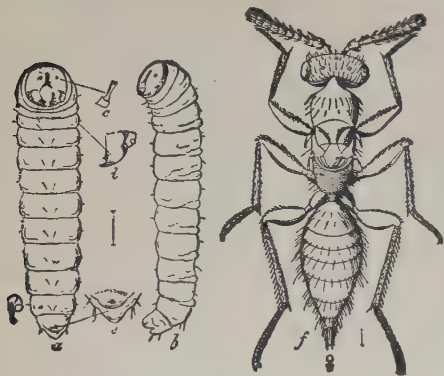

FIG. 404. Wheat straw-worm, spring generation. (Much enlarged)

a, *b*, larvæ; *f*, female. (After Riley, United States Department of Agriculture)

FIG. 405. Ants attending aphids. (Slightly enlarged)

(Photograph by Weed)

they are so fond. Wherever aphides which produce honey-dew are abundant, the ants will be found watching over them, warding off parasites and often transporting them from plant to plant when food becomes scarce. Now and then an ant may be seen to tap an aphis with its antennæ, when a drop of the honey-dew will be exuded and greedily lapped up. So well do they herd them that the aphides have been aptly called the ants' little green cattle. The relation of some ants to plant-lice is most remarkable, as in the case of the little brown ant (*Lasius niger americanus*) which cares for the eggs of the corn root-aphis in its nest over winter and then carries the aphides to the roots of weeds and grasses and then to corn roots in the spring. It is this relation of the ants to aphides which makes many species of decided economic importance to the farmer and necessitates his destroying them as far as possible. There are several families of ants, but most of our common forms are included in two large families.

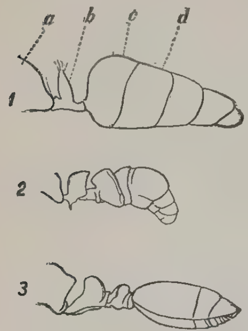

FIG. 406. Lateral aspects of abdomens of three families of ants

1, *Camponotidae*; *2*, *Poneridae*; *3*, *Myrmicidae*; *a*, thorax; *b*, first abdominal segment; *c*, second abdominal segment; *d*, third abdominal segment. (After Kellogg)

The typical ants (*Camponotidae*) have but one segment to the petiole of the abdomen, and have no sting. The large, black carpenter-ant (*Camponotus pennsylvanicus*), which tunnels out dead or dying trees, logs, and timbers, is a well-known example of one of our larger species, and the little brown ants of the genus *Lasius* make their nests along roadways and in pastures and meadows, and include the species which care for the corn root-aphis and other injurious plant-lice. Some of the species make large mounds for their homes, and others are slaveholders, capturing the ants of other colonies and maintaining them in servitude.

Stinging ants. In the *Myrmicidae* the petiole of the abdomen is composed of two segments, and most of the females bear a sting. The little red ant (*Monomorium pharaonis*) which often infests our pantries is well known, but fortunately has no sting. The so-called agricultural-ants of the southwest belong to this group. Their

FIG. 407. The red ant (*Monomorium pharaonis*). (Enlarged)
a, female; *b*, worker. (After Riley)

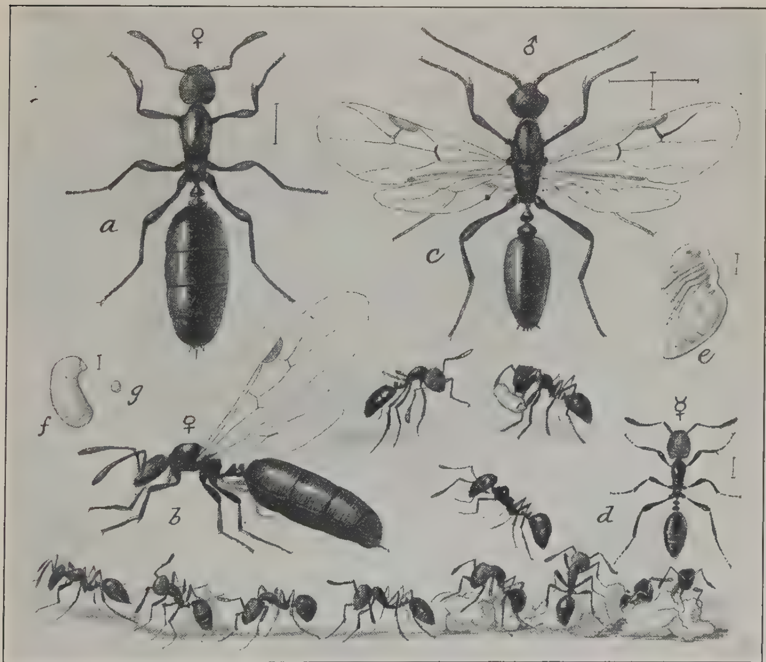

FIG. 408. The little black ant (*Monomorium minutum*). (Much enlarged)
a, female, or queen; *b*, same with wings; *c*, male; *d*, workers; *e*, pupa; *f*, larva; *g*, egg of worker. (After Marlatt, United States Department of Agriculture)

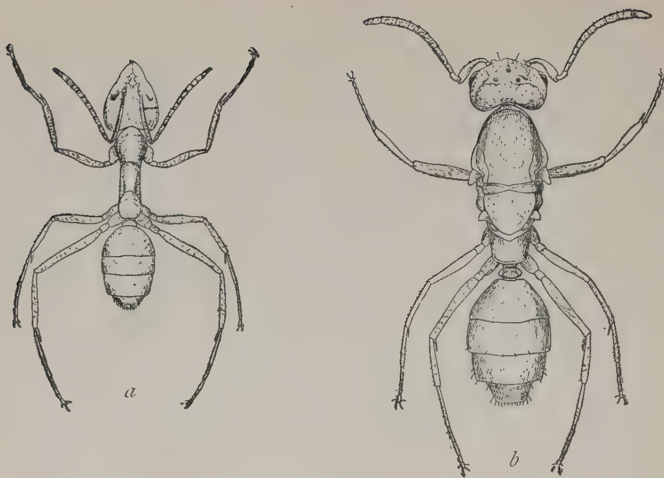

FIG. 409. The Argentine ant (*Iridomyrmex humilis* Mayr.)
a, worker; *b*, fertile queen. (After Newell)

FIG. 410. Mound nest of western agricultural-ant (*Pogonomyrmex occidentalis* Cress.), showing entrance hole in mound, and cleared space around it
(After Headlee and Dean)

nests are made underground, and around the entrance all vegetation is cleared off and regular runways radiate out among the neighboring grasses, the seeds of which are stored in the nest and furnish food. A few years ago a species was imported into New Orleans from Argentina, known as the Argentine ant (*Iridomyrmex humilis*), and has now spread over Louisiana and neighboring states, becoming a very serious household pest as well as attacking vegetation. Another common species of this family (*Solenopsis geminata*) is one of the most important enemies of the larvæ of the cotton-boll weevil. It will thus be seen that our common ants are of very diverse habits and of varying economic importance. They are much more abundant in

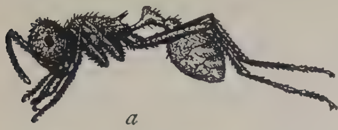

FIG. 411. Western agricultural-ant, or mound-building prairie ant (*Pogonomyrmex occidentalis*). (Enlarged)

a, worker; *b*, queen. (After Headlee and Dean)

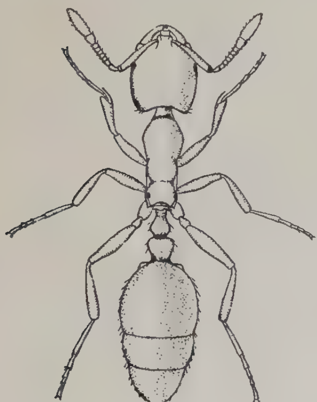

FIG. 412. *Solenopsis geminata* Fab., a native ant which is a valuable enemy of the cotton-boll weevil. (Much enlarged)

(After Hunter and Hinds, United States Department of Agriculture)

FIG. 413. Work of the black carpenter-ant (*Camponotus pennsylvanicus*) in black spruce

The injury to the living tree allowed the ants to enter, so that the heartwood was completely destroyed by them and the tree fell. (After Hopkins)

the South, and in the tropics become veritable pests. Various artificial nests have been devised whereby colonies may be maintained indoors for study, for which no insects are of more interest.[1]

2. WASPS

Every small boy soon makes the acquaintance of the bees and wasps, which he naturally classes together from their ability to sting most painfully. The males, however, are entirely harmless, but

FIG. 414. A digger-wasp (*Ammophila* sp.). (Natural size)

a, wasp putting an inch-worm into its nest burrow; *b*, the nest burrow with food for the young, paralyzed inch-worms in bottom and burrow nearly filled; *c*, wasp bringing a bit of material to put over the filled nest burrow. (From life, after Kellogg)

unfortunately we have no means of recognizing them in the field. The wasps may be distinguished from the bees by the first segment of the hind tarsus being cylindrical and naked, and the body hairs being simple and unbranched.

Digger-wasps (***Sphecina***). Several families of wasps are grouped together under this name, which is due to their habit of digging

[1] See Kellogg's "American Insects," p. 548.

holes in the ground or in wood, in which their nests are made. They are distinguished from the true wasps (*Vespina*) by the wings lying flat on the body when at rest. They are solitary forms, each female making her own nest in which the eggs are laid, and provisioning it with spiders, caterpillars, or other insects, upon which the larvæ feed. The food is stored alive in a remarkable manner. The female seizes the spider or insect and stings it in the nerve ganglia of the thorax, thus paralyzing it so that it remains alive but helpless. The prey thus paralyzed is placed in the burrow, the egg is laid with it, and the tube is then sealed up, several compartments usually being made, one after another. When the egg hatches, the young larva finds an abundant supply of well-preserved food for its nourishment. Many of the nests are made in burrows in sandy banks, others in the pith of plants, such as the sumac and elder, while others make mud nests or tubes, as do the common mud daubers.

FIG. 415. A velvet-ant (*Sphaerophthalma simillima*), female. (Four times natural size)

(After Lugger)

Velvet-ants (*Mutillidae*). In the warmer parts of the country one will often see large, antlike insects thickly covered with black, red, or yellow hair, which has given them this name. The males are winged, but the females are wingless and can sting severely. One of the largest species is bright scarlet and black, two thirds of an inch long, and provisions its burrows, made in beaten paths, with flies and other insects, though it is known to enter beehives and kill bees.

The spider-wasps (*Psammocharidae*) are slender, long-legged, blackish wasps with reddish or black wings, the body often marked with red or orange; they provision their nests with spiders. They are mostly medium-sized wasps, though the tarantula hawk (*Pepsis formosa*), which preys upon the tarantulas of the southwest, is

the largest species of the order, being nearly two inches long and having a wing expanse of over three inches. Not infrequently it is overpowered and destroyed by its formidable prey.

FIG. 416. The tarantula-killer (*Pepsis formosa*). (Natural size)

The thread-waisted wasps (*Sphecidae*) are readily recognized by the very long, threadlike petiole of the abdomen, and include our common mud-daubers, which make their nests under the eaves of buildings and in barns, attics, etc. The nests are composed of several tubes placed side by side, each of which is provisioned with spiders. They may be seen around pools, collecting mud for their nests, and jerking their wings from side to side in a nervous manner.

FIG. 417. A mud-dauber (*Pelopaeus cementarius*)
(After S. J. Hunter)

A nearly related family (*Bembecidae*), which burrows in the sand and provisions its nests with flies and similar insects, includes the large cicada-killer. This is

one of our largest wasps, one and one fourth inches long, black or rusty in color, with the abdomen banded with yellow, which pounces upon a cicada and carries it off to its burrow in the ground as food for the larva. Other nearly related families of digger-wasps make their nests in the pith of plants or bore into more solid

FIG. 418. Mud-dauber wasp (*Pelopaeus* sp.) and nest. (Natural size) (After Linville and Kelly)

wood, or often use the deserted burrow of some other insect (such as some of the bees which have similar habits), provisioning them with flies, spiders, and various insects.

The true wasps (*Vespina*) may be distinguished from the digger-wasps by having the wings folded on the back like a fan when at rest, and the legs are not adapted to burrowing, being free from spines and bristles. The solitary-wasps (*Eumenidae*) resemble the

digger-wasps in their habits, making burrows in the earth or in wood, or forming their nests of mud and provisioning them with insects. One of our common species (*Eumenes fraternus*) makes a little mud nest on the twigs of bushes and trees, which looks like a miniature water-jug. The young are fed on caterpillars, and enjoy cankerworms when these are available. Other species of this family look like small yellow-jackets. The Social-wasps (*Vespidae*) live in colonies and, besides males and females, have a form of undeveloped females known as workers, all of which are winged. They build their nests either in the ground or attached to bushes, trees, or buildings, and construct them of paper made from bits of wood chewed up and formed into a paste, for they discovered the possibility of making paper from wood pulp long before man thought of it. They are very jealous of their homes and enforce a wholesome respect for them upon whoever even accidentally disturbs them, as every one who has attacked a nest of yellow-jackets or hornets is

FIG. 419. Female *Sphecius speciosus* carrying cicada to her burrow. (Natural size)

(After Riley, United States Department of Agriculture)

FIG. 420. The fraternal potter wasp (*Eumenes fraternus*) and its earthen nest

(Photograph by Weed)

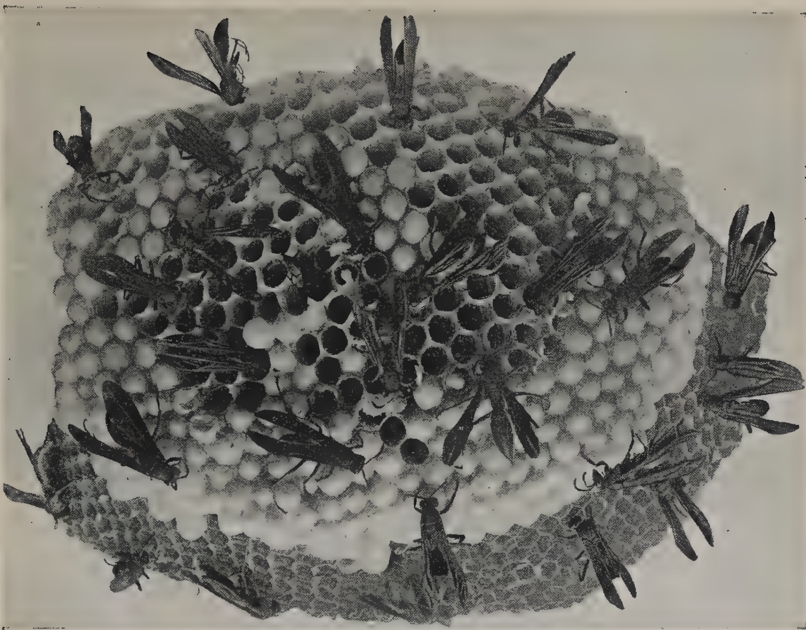

FIG. 421. *Polistes annularis* and its nest. (Two thirds natural size)
(After Quaintance and Brues, United States Department of Agriculture)

FIG. 422. Nest of yellow-jacket (*Vespa* sp.); at right, nest opened to show combs
(Photograph by Weed)

well aware. The adults are predacious and feed their young on insects which have been masticated. Not infrequently, where an outbreak of caterpillars occurs, wasps will be seen carrying them off to their nests in considerable numbers; we have observed them at work on the cotton boll-worm and leaf-worms in the South. But two genera are common in the East. *Polistes* are black ringed with yellow, or are brownish, and have long, spindle-shaped abdomens. Their nests are composed of a single comb and are attached by a short stem. The genus *Vespa* includes the hornets and yellow-jackets, which are black, spotted or banded with yellow, or yellowish-white, with a short, stout body, and the abdomen attached by a very short peduncle. Their nests are formed of several layers of combs, all of which are covered with a waterproof covering of paper, made from weatherworn wood of stumps, trees, fences, and buildings. The nests are gradually enlarged, new combs being added and the outer envelope being enlarged to cover them. The males and workers die in the fall, and the females hibernate over winter and start a new colony in the spring.

FIG. 423. White-faced wasp (*Vespa maculata*)

3. BEES (*APINA*)

Most of our common bees are readily distinguished as such by the general shape and hairy clothing of

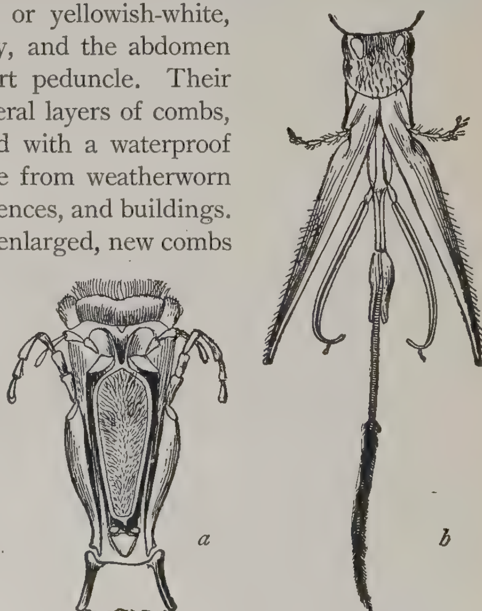

FIG. 424. *a*, mouth-parts of a short-tongued bee (*Prosopis pubescens*) (note short, broad, flaplike tongue, or glossa); *b*, mouth-parts of a long-tongued bee (*Anthophora pilipes*) (note greatly extended tongue). (Much enlarged)

(After Sharp, from Kellogg)

the body. Some of them, however, may be confused with some of the wasps, from which they may be separated by the structure of the first segment of the hind tarsus (which is dilated, flattened, and usually provided with numerous hairs to aid in carrying pollen) and also by the fact that the body hairs are covered with short branches instead of being simple, as in wasps. They are quite variable in habit: some are solitary, — that is, each female makes a nest for her young, as do the solitary wasps; others lay their eggs in the nests of other bees; while others, of which the honey-bee is the best example, live in colonies. The nests may always be recognized, however, by their being stored with pollen and honey and never with insects. Two families are recognized, which are distinguished by the length of the tip of the labium, or glossa.

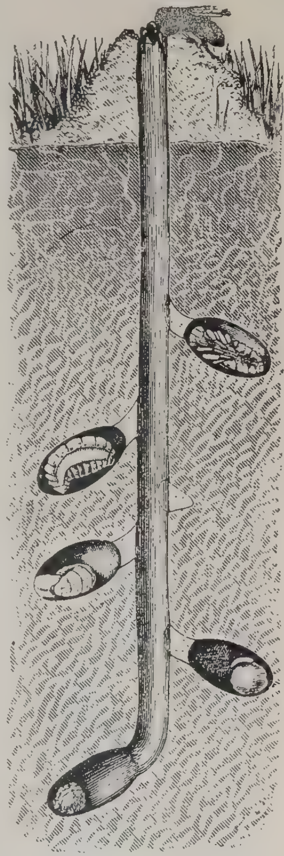

FIG. 425. Nest of *Andrena*, the mining bee (After Packard)

In the Short-tongued bees (*Andrenidae*) the tip of the labium is shorter than the base, while in the Long-tongued bees (*Apidae*) it is much longer and enables them to secure the nectar from deeper flowers. All of the bees are of great economic importance, for as they go from flower to flower the pollen becomes attached to the hairs of the body as well as to the special structures on the legs, by which they transport it, and is brushed off on the stigma of the next flower visited. Thus the bees are the most important agents in the cross-fertilization of flowers, without which many plants will not set their seed or fruit. For this reason those who grow cucumbers and tomatoes under glass always have a hive of bees to fertilize the flowers, and where bees are scarce, many of our common fruits set but sparingly.

None of the short-tongued bees live in colonies, and many of them make their nests in the ground, which has given them the name of "mining bees." Their tunnels are usually branched, each branch terminating in a single cell, which is lined with a sort of glazing. After this cell is filled with nectar and pollen, the egg is laid and the cell is then sealed up. Quite commonly, large numbers of these tunnels will be found near together, forming large villages. Some of the smaller forms mine into the sides of sand banks and cliffs, their numerous holes making the surface appear as if it had received a charge from a shotgun. These little females of the genus *Halictus* have the interesting habit of making a common burrow into a bank and then each making a side passage to her own cells, so that, as Professor Comstock aptly remarks, "While *Andrena* builds villages composed of individual homes, *Halictus* makes cities composed of apartment houses."

FIG. 426. A common short-tongued bee (*Andrena* sp.). (Slightly enlarged)

FIG. 427. A mining-bee (*Halictus lerouxii* var. *ruborum* Ckll.). (Slightly enlarged)

FIG. 428. The leaf-cutter bee and a leaf-covered cell removed from its burrow. (Natural size)

(After Linville and Kelly)

The majority of the Long-tongued bees (*Apidae*) are solitary and have most diverse nesting habits: some make their cells in the ground, as do the miners; others are potters, and fashion nests of mud, which are attached to the stems of plants; some are carpenters, boring holes in wood; while some go so far as to upholster their nests with neatly cut pieces of leaves, with which the cells are lined and covered. The leaf-cutter bees are peculiarly interesting forms, though of no particular economic importance. They bore a hole in soft or decaying wood, in the bottom of which is deftly fitted a piece of a leaf, rose leaves being commonly used, so as to make a thimblelike cup. In this the pollen and nectar are placed and an egg is laid, and then a circular-shaped piece of leaf is jammed down so as to make a tight wad over the cell, and another similar cell is made above it. The circular areas cut from rose leaves by these bees may frequently be noticed. Others are known as carpenter-bees, making their nests in wood. The smaller carpenter-bee (*Ceratina dupla*) inhabits the dead stems of sumac or the hollow stems of other plants, which are cleaned out and used over again by the young. Several cells are made and separated by little chips. When the tunnel is full, the female waits for her children to grow up. "The lower one hatches first," says Professor Comstock, "and after it has attained its growth, it tears down the partition above it, and then waits patiently for the one above to do the same. Finally, after the last one in the top cell has matured, the mother leads forth her full-fledged family in a

FIG. 429. Nest of carpenter-bee. (Reduced)

(After Jordan and Kellogg)

FIG. 430. *a*, carpenter-bee (*Xylocopa carolina* Linn.); *b*, first segment of hind tarsus; *c*, same of bumble-bee

(After Walsh)

flight into the sunshine." The larger carpenter-bee (*Xylocopa virginica*) closely resembles a bumble-bee, being fully as large, yellow and black in color, with a metallic blue reflection on the abdomen. It excavates its nests in solid wood, often boring for a foot or more.

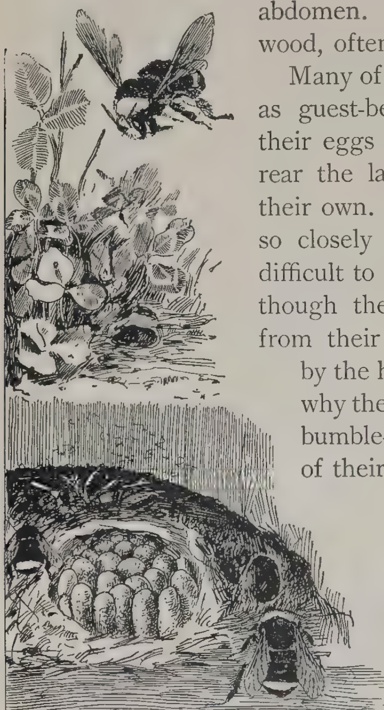

Fig. 431. Nest of bumble-bee (*Bombus* sp.), showing opening at the surface of the ground and also brood cells in the cavity beneath

(Adapted from McCook by Kellogg)

Many of the long-tongued bees are known as guest-bees, from their habit of laying their eggs in the cells of other bees, which rear the larvæ of the intruders as they do their own. The largest of these (*Psythirus*) so closely resemble bumble-bees that it is difficult to distinguish them from the males, though the females are readily recognized from their lacking the pollen-basket borne by the hind-legs of the bumble-bees. Just why they are tolerated is a mystery, for the bumble-bees allow them to go in and out of their nests with the greatest freedom.

The social bees include our common bumble-bee and the domesticated honey-bees. The bumble-bees are of considerable importance to the farmer, for they are the only ones whose tongues are long enough to feed on red-clover blossoms, so that they are entirely responsible for its pollination, and where they are scarce it is difficult to secure a crop of clover seed. It is hardly necessary to describe the nest of a bumble-bee, for what country boy does not look back upon the stirring experiences incident to the robbing of their nests, or of accidentally disturbing one while mowing, and being given good reason to remember the fact. The queens are larger than the males or workers, and are the only forms which live over winter. In the spring the queen finds some deserted mouse nest and within it places a ball of pollen and her eggs. The larvæ feed on the pollen and, when full

grown, make strong, brown, silken cocoons, in which they change to pupæ. These cocoons are strengthened with wax by the queens, and are used for storing honey, after the young emerge. The first broods are all workers, and after their appearance the queen has nothing more to do but lay her eggs. Later in the season the males and other queens appear, all living together in the same nest. In the fall the young queens crawl away to a suitable hibernating place, and in the spring start new colonies, in the manner previously described.

FIG. 432. Bumble-bees

a, worker; *b*, queen, or fertile female. (After Jordan and Kellogg)

Honey-bees. Probably no other insect is of quite as much human interest as the honey-bee. Apiculture is a well-developed art, its literature is extensive, and its devotees have well-organized associations. The honey-bee was brought from Europe by the early settlers of this country, and swarms have escaped, which have become the wild bees now found in hollow trees. There are three forms in every hive, — the queen, the drones, or males, and the workers, which are imperfectly developed females. The workers are the common forms with which we are familiar, and which do all the work of the colony. The drones are larger than the workers, are reared in larger cells, and are blunter and broader in shape. They are relatively few in number, and occur only in the early summer, during the swarming season, after which they are expelled from the nest or killed by the workers.

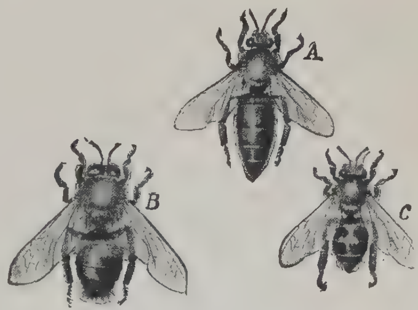

FIG. 433. The honey-bee (*Apis mellifica*)

A, queen; *B*, drone; *C*, worker. (After Kellogg)

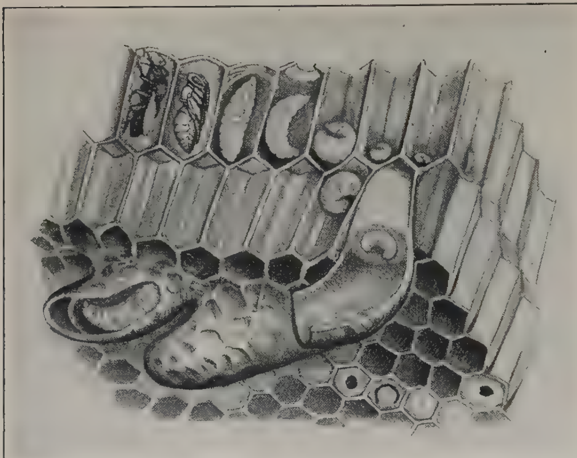

FIG. 434. Queen cells of the honey-bee, and worker brood in various stages

(After Benton, United States Department of Agriculture)

The queen bee is much larger than the worker, and has a long, pointed body. She is developed in a special cell several times the size of an ordinary cell and readily distinguishable, as it extends at a right angle to the other cells. The larvæ are all fed by the workers, who provide honey and bee-bread, composed of pollen and nectar, for the ordinary cells which are to develop workers and

FIG. 435. Honey-bees building comb (side of hive removed)

(After Benton, United States Department of Agriculture)

drones, but for the queen cell a royal jelly, which is excreted from the mouths of the workers and is very nutritious. Any worker egg may be developed into a queen at the desire of the workers by enlarging the cell and feeding the larva with this royal jelly. In the spring new queens appear in the colony, which are defended from the old queen by the workers, when the old queen, with many of her subjects, forms a new swarm and goes off to start a new colony, thus insuring the multiplication and continuance of the species. The comb is made of wax, and is constructed in thin, hexagonal cells so as to use as little material as possible, for it takes twenty-one pounds of honey to make one pound of wax. To secure the wax, some of the workers gorge themselves with honey and hang in a curtainlike mass in the hive. In a day or so the wax commences to exude from the wax plates on the underside of the abdomen and is scraped off and used by other workers in constructing the comb. From the buds of various trees, particularly the poplar, they collect a sort of resin, called propolis, which is used for cementing crevices in the hive. The

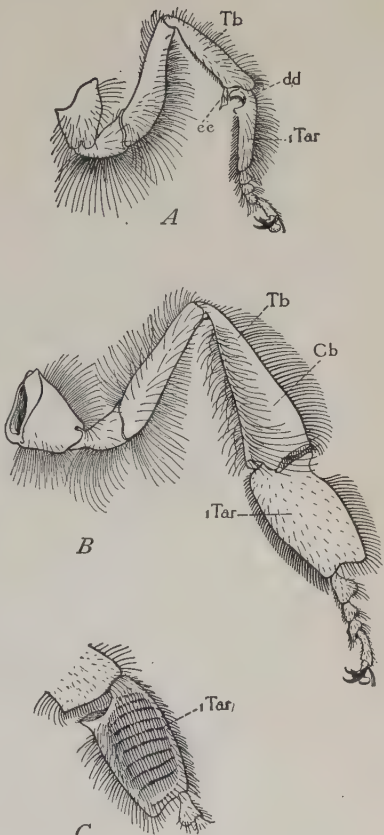

FIG. 436. Legs of the honey-bee

A, left front leg of worker (anterior view), showing position of notch (*dd*) of antenna cleaner on base of first tarsal joint (*1 Tar*) and of closing spine (*cc*) on end of tibia (*Tb*); *B*, left hind-leg of worker (anterior view), showing the pollen-basket (*Cb*) on outer surface of tibia (*Tb*); *C*, inner view of first tarsal joint of hind-leg of worker, showing rows of pollen-gathering hairs and the so-called "wax shears." (After Snodgrass, United States Department of Agriculture)

bee-bread on which the larvæ are fed is made from the pollen of flowers and is carried to the nest on the hind-legs, which have a hair-encircled area, called the pollen-basket, for transporting it. The honey is stored for food during the winter, and is made from the nectar of flowers, which is taken into the honey-stomach, where it is changed to honey, and is then regurgitated into the cells of the comb.

Summary of the Hymenoptera

Suborder I. Boring Hymenoptera (*Terebrantia*). With ovipositor and two-segmented trochanters.

- Section 1. Plant-eating Hymenoptera. Abdomen not constricted.
  - Family. Saw-flies (*Tenthredinidae*).
  - Horn-tails (*Siricidae*).
- Section 2. Gall-inhabiting Hymenoptera (*Cynipidae*).
- Section 3. Parasitic Hymenoptera. Abdomen petiolate.
  - Family. Ichneumon-flies (*Ichneumonidae*).
  - Braconid-flies (*Braconidae*).
  - Chalcis-flies (*Chalcididae*).
  - Proctotrypid-flies (*Proctotrypidae*).

Suborder II. Stinging Hymenoptera (*Aculeata*). Females bearing a sting; simple trochanters.

- Section 1. Ants (superfamily *Formicina*).
  - Family. Common ants (*Camponotidae*).
  - Stinging ants (*Myrmicidae*).
- Section 2. Wasps. First segment of metatarsi cylindrical; hairs simple.
  - *A*. Digger-wasps (superfamily *Sphecina*).
    - Family. Velvet-ants (*Mutillidae*).
    - Spider-wasps (*Psammocharidae*).
    - Thread-waisted wasps (*Sphecidae*).
    - Bembecids (*Bembecidae*),
    - and others.
  - *B*. True wasps (superfamily *Vespina*). Wings folded fanlike on back when at rest.
    - Family. Solitary wasps (*Eumenidae*).
    - Social wasps (*Vespidae*).
- Section 3. Bees (superfamily *Apina*). First segment of metatarsi, broad, flattened, hairy; body hairs, plumose.
  - Family. Short-tongued bees (*Andrenidae*).
  - Long-tongued bees (*Apidae*).
    - Solitary bees, guest-bees, social bees.

PART III. LABORATORY EXERCISES

CHAPTER XVI

THE EXTERNAL ANATOMY OF THE LOCUST

NOTE. Beyond a doubt, one of the most difficult problems every instructor in the biological laboratory has to meet is to determine the amount of assistance which shall be given individual students. In advanced work, probably the best plan is to train students to rely on their own resources and to solve their own problems. In elementary classes, however, far too much time is often wasted in the laboratory because the instructor does not happen to be at hand to aid and direct the student. For this reason the following instructions are given, more or less in detail, with the hope that the students may intelligently carry on their work without the constant attention of the instructor.

In order to derive the most benefit from the laboratory work, it is essential that the students should verify every detail of structure herein given before proceeding with the drawings, the latter being considered simply as a means to an end. In fact, the amount of good derived by the student from the laboratory work is largely dependent upon the energy of the individual. For this reason the laboratory work should not be judged entirely by the drawings, and, if possible, the actual amount of information obtained by the student in the laboratory should be determined by examinations similar to those given in lecture or recitation work.

For details concerning laboratory methods and equipment, see Chapter XXIII.

SECTION I. EXTERNAL ANATOMY OF THE GRASSHOPPER (TYPE OF CLASS INSECTA)

Material. The red-legged locust (*Melanoplus femur-rubrum*) has been selected as the type of the class Insecta, partly on account of its abundance and the ease with which it may be collected, and partly on account of its simplicity of structure. Specimens for class work should be collected in the late summer or early fall, and preserved in 85 per cent alcohol for three or four days. After this time has elapsed, they should be transferred to 80 per cent alcohol, to which 10 per cent of pure glycerin has been added. If soaked in warm water a short time before using, the specimens will be rendered soft and pliable. The students should verify the following points:

1. Body covering. Carefully examine with a hand lens the body covering of the specimen, and note that it is made up of a series

of hardened plates. These plates are known as sclerites, and the depression between two plates is called a suture. The hardness of the plates is due to the deposition of a horny substance called chitin.

2. General divisions of the body. Typically the bodies of all insects are divided into a series of rings, or segments. In many places two or more of these rings have grown together, or are fused. Again, in certain regions of the body, parts of the segments may be lost. Regardless of the amount of variation in this respect, however, we find that the segments are always grouped into three regions, known as head, thorax, and abdomen.

a. *The head.* The head is made up of a number of segments, which are fused together, forming a boxlike structure. On the head are found the eyes, mouth-parts, and antennæ.

b. *The thorax.* This is the second division of the body, and consists of three segments, known as the prothorax (division nearest the head), mesothorax, and metathorax. Each of these segments bears a pair of walking appendages, and in addition the mesothorax and metathorax are provided with wings.

c. *The abdomen.* This is the third division of the body, and is made up of eleven segments. The posterior segments, however, are not complete, showing modifications.

Exercise 1. Pin the specimen to the bottom of a dissecting dish, spread the wings and wing-covers of one side, and make an enlarged drawing (dorsal view) of the entire insect, showing the above-named divisions.

3. Detailed study of the head. As already noted, the head of the locust is made up of a number of segments which have been firmly fused together. The following divisions should be noticed :

a. *The epicranium.* This is a boxlike piece which surrounds the eyes and forms the basis of attachment for the movable parts of the head. It extends down the front of the head, between the eyes, to the transverse suture, and down the sides of the head to the base of the mouth-parts. The sides of the epicranium below the compound eyes are known as the genæ, or cheeks, while the front of the head between the compound eyes is called the frons.

b. *The compound eyes.* These are situated upon the upper portion of the sides of the head, and are large, brown, oval areas with

smooth, highly polished surfaces. If examined with a lens, the surface will be seen to be made up of a number of hexagonal areas, which are known as facets.

c. *The ocelli.* These are sometimes called the simple eyes, and consist of three very small, almost transparent oval areas. One of the ocelli is situated on the front of the head just below the lowest margin of the compound eyes; the other two are placed in the top of the impression which contains the bases of the antennæ, and in contact with the upper portion of the compound eyes.

d. *The antennæ.* These are two long, threadlike processes situated median to the compound eyes. Each consists of about twenty-six segments. Each antenna arises from an oval depression known as the antennary fossa, and is attached by a thin membrane which admits of motion in all directions.

e. *The clypeus.* This is a short, rectangular piece attached to the lower straight edge of the epicranium.

f. *The mouth-parts.* These consist of a number of separate parts attached to the ventral region of the epicranium, and will be studied in detail later.

Exercise 2. Make an enlarged drawing of the front of the head, showing the above parts.

Exercise 3. Make an enlarged drawing of the side of the head, showing all the parts.

Exercise 4. Remove the head and notice the occipital foramen, or the large opening by which the cavity of the head communicates with that of the neck and thorax.

Section II. Mouth-Parts of Locusts

Material. In order to effectively study the mouth-parts of the locust each student should be provided with prepared slides as well as with the alcoholic specimens. As the parts are removed for study they should be mounted on glass slides in a glycerin solution, and may then be compared with the prepared mounts. The parts may be removed by grasping them at their attachment with a pair of stout forceps and pulling them back at right angles to their attachment.

1. Labrum. The labrum, or upper lip, is a flaplike piece attached to the lower edge of the clypeus. The free edge is deeply notched on the median line.

2. Mandibles. These lie directly beneath the labrum and consist of a pair of short, thick pieces. The inner edge is somewhat flattened and provided with a number of toothlike projections which form the grinding surface of the mandibles.

3. Maxillæ. These are the second pair of jaws; they lie directly beneath the mandibles and are much more complicated in structure. After they have been removed and mounted in glycerin, the following parts can be distinguished:

a. *The cardo.* This forms the attachment or basal piece of the maxilla, and is triangular in shape.

b. *The stipes.* This is a quadrangular-shaped segment forming the central part of the maxilla. One side is attached to the cardo, and two of the other sides form the attachment for the remaining structures.

c. *The lacinia.* This is attached to the inner edge of the stipes, and is a long, curved piece terminating in a row of sharp teeth.

d. *The galea.* This portion of the maxilla articulates with the stipes on its outer edge, just below the attachment of the lacinia. It closely resembles this latter structure, except that the end is rounded instead of being toothed.

e. *The maxillary palpi.* These arise from a basal portion known as the palpifer, which articulates with the stipes between the attachment of the galea and the cardo. The palpi consist of five long, slender segments, and, like the antennæ, are sensory in function.

4. Labium. The labium, or under lip, forms the under part of the mouth and, together with the upper lip, almost incloses the mandibles and maxillæ. The labium is a complicated structure made up of the following parts:

a. *The submentum.* This forms the attachment to the epicranium and is a crescent-shaped piece. It is also joined to the membrane which connects the head with the thorax.

b. *The mentum.* This is the central portion of the labium, and is joined to the distal margin of the submentum.

c. *The ligula.* The ligula consists of two large, movable flaps attached to the distal, or outer, edge of the mentum, and forms the terminal, central portion of the labium.

d. *The labial palpi.* These resemble the maxillary palpi, but consist of only four segments, which are attached to the palpifers. These are located on each side of the mentum, below the attachment of the ligula.

5. Hypopharynx. The hypopharynx, or tongue, is located on the floor of the mouth, between the maxillæ. It is diamond-shaped when viewed from above, and is covered with numerous small taste setæ.

Exercise 5. Make a careful drawing of the mouth-parts, showing all of the above-named structures.

SECTION III. THE THORAX

Material. Each student should be provided with both alcoholic and dry specimens, and should remove the wings and legs from one side of the body only.

1. Divisions of the thorax. As has already been noted, the thorax is divided into three segments, known as the prothorax, mesothorax, and metathorax.

2. Prothorax. This is the segment to which the head is attached, and may be divided into two regions, — a dorsal region known as the pronotum, and a ventral region known as the sternum.

a. *The pronotum.* This is a bonnetlike piece extending over the dorsal and lateral region of the prothorax. It is made up of a fusion of four plates, which are indicated by the transverse sutures. Anteriorly there is an opening corresponding to the occipital foramen of the epicranium.

b. *The sternum.* The ventral side, or sternum, of the prothorax is also made up of separate plates, or sclerites. The anterior sclerite bears a spine on the median line.

c. *The prothoracic legs.* These arise from the ventral, lateral region of the prothorax. Their structure will be noted later.

3. Mesothorax and metathorax. The sclerites of these two segments are very intimately associated, and their structure will be discussed together. The mesothorax is joined to the prothorax by a membrane which permits of more or less movement. Posteriorly the metathorax is joined immovably with the first abdominal segment. The mesothorax and metathorax form a strong, boxlike structure for the support of the wing and leg muscles. Like the prothorax

these segments are made up of separate plates, held together by a tough, connecting membrane. These plates may, however, be divided into three groups: the tergum, or dorsal region; the sternum, or ventral region; and the pleuron, or lateral region. On the dorsal and ventral regions of the body the sutures separating the mesothorax from the metathorax are not very distinct. On the sides of the body, however, there is a very distinct line, or suture, running from the posterior border of the attachment of the second pair of legs toward the dorsal part of the body. This suture divides the mesothorax from the metathorax. The pleura of each of the posterior thoracic segments are again divided by transverse sutures, so that each pleuron consists of two sclerites.

a. *The legs.* The mesothoracic and metathoracic legs arise from the lower posterior border of the pleura of their respective segments, and are joined to the thorax by a tough, elastic membrane.

b. *The wings.* The wings have a more anterior origin in respect to their thoracic segments than do the legs. Each pair arises at the union of the pleura and tergum.

c. *The spiracles.* The spiracles, or openings of the respiratory system, consist of two pair of liplike structures situated on either side of the body on the anterior margin of the pleural plates. The mesothoracic spiracle is concealed by the posterior edge of the pronotum. The metathoracic spiracle is located just dorsal to the mesothoracic leg, near the suture separating the two segments. There is another spiracle just dorsal to the attachment of the metathoracic leg, but this belongs to the first abdominal segment.

Exercise 6. Make a full-page drawing of a side view of the thorax of a locust with the wings and legs removed, showing all of the parts noted above.

Section IV. The Thoracic Appendages

Material. With a pair of fine-pointed scissors remove the legs from one side of the body of the locust and arrange them on a piece of white paper in their regular order. Also remove the wing and wing-cover (mesothoracic wing) from one side and pin to a thin sheet of cork, spreading the wing to its full dimension.

1. Legs. Make a comparative study of the legs, which will be found to consist of the following segments:

a. *The coxa.* This is the first segment, and is attached to the thorax by a tough, elastic membrane. It is short, almost globular, and is more distinct on the prothoracic legs than on the other two.

b. *The trochanter.* This is the second segment, and is considerably shorter than the coxa, and partially or entirely fused with the next segment. It is hard to distinguish except in the first pair of legs.

c. *The femur.* This is the third and largest segment of the leg, and in the case of the metathoracic leg contains the muscles used in jumping.

d. *The tibia.* This is the fourth segment, and is much more slender than the femur, although about equaling it in length.

e. *The tarsus.* This is the last division, and is made up of three short segments freely articulating with each other. These segments bear a series of pads, which terminate on the last one in a large, suckerlike disk known as the pulvillus. On each side of the pulvillus is a pair of claws, the ungues.

Exercise 7. Make drawings of the first and third thoracic legs, showing all the parts.

2. Wing-covers. The wing-covers are leathery in texture and do not fold fanlike over the abdomen, as do the two wings. They are strengthened by numerous veins and cross veins.

Exercise 8. Make an enlarged drawing of a wing-cover, noting the arrangement and number of the veins and cross veins; also note the attachment to the mesothorax.

3. Wings. These are sometimes called the second, or metathoracic, wings. They are membranous in texture and fold fanlike when not in use. They are also strengthened by numerous veins and cross veins, as are the wing-covers.

Exercise 9. Make an enlarged drawing of a wing, showing the arrangement of the veins, method of folding, attachment, etc.

Section V. The Abdomen

Material. Each student should be provided with one alcoholic specimen each of the male and the female locust. The remains of the specimens used in previous sections will be sufficient.

1. Abdomen of the male. The abdomen of the male locust consists of eleven segments; only seven of these, however, are complete.

a. *The first abdominal segment.* This is made up of a curved, dorsal shield, the tergum, which terminates just above the attachment of the third pair of legs. This piece partially surrounds the tympanic membrane, or ear, which is a large, crescent-shaped area covered with a semitransparent membrane. Between the ear and the attachment of the legs are the spiracles, which have already been noted. The ventral part of the first segment, the sternum, is not attached to the tergum, owing to the large size of the attachment of the legs. The pleura are entirely absent.

b. *The second to eighth abdominal segments.* These are all quite similar, consisting of a dorsal tergum, which extends laterally to near the ventral part of the body, where it joins the sternum. The pleura, or side pieces, noted in connection with the thorax, have been inseparably fused to the tergum. One pair of spiracles is located at the anterior margin of each segment near the union of the sternum and tergum.

c. *Segments nine and ten.* The terga of these two segments are partially fused together, the union of the two being indicated by the presence of a transverse suture. The sterna of these two segments are entirely fused and much modified, forming a broad, platelike piece.

d. *Segment eleven.* This is represented only by the tergum, which forms the terminal, dorsal, shield-shaped piece.

e. *The cerci.* These are a pair of plates attached to the lateral, posterior border of the tenth segment, and extend back past the end of the eleventh tergum.

f. *The subgenital plate.* This is attached to the ninth sternum and forms the most posterior ventral plate of the body.

g. *The podical plates.* These lie directly beneath the cerci and ventral to the eleventh tergum. The anus opens between these plates, and the genital chamber lies directly below them.

Exercise 10. Make an enlarged drawing of the side view of the abdomen of the male locust, showing all of the above parts.

2. Abdomen of the female. The abdomen of the female from the first to the seventh segment is nearly the same as in the male.

a. *Segment eight.* This segment resembles the other segments, except that the sternum is nearly twice as long, and is known as the subgenital plate.

b. *Segments nine, ten, and eleven.* These are essentially like those of the male, the tergum of nine and ten being partially fused, and tergum eleven forming the terminal, dorsal shield.

c. *The cerci and podical plates.* These plates are similar to those in the male, except that the podical plates are much more prominent.

d. *The ovipositor.* The ovipositor consists of three pairs of movable plates. The dorsal pair lie just ventral to the eleventh tergum and are long, lance-shaped pieces with hard, pointed tips. The ventral pair arises just dorsal to the eighth sternum and resembles the dorsal pair. When these four pieces are brought together, their points are in contact, forming a sharp organ by means of which the female bores the holes in the ground in which to deposit her eggs. The third set of plates are known as the egg guides. These are much smaller and are located median to the plates of the true ovipositor.

Exercise 11. Make a drawing of the side view of the last five segments of the female locust.

CHAPTER XVII

A COMPARISON OF THE DIFFERENT TYPES OF ARTHROPODA

SECTION VI. COMPARISON OF INSECTS AND CRUSTACEANS (TYPES, LOCUST AND CRAYFISH)

Material. Alcoholic specimens of both crayfish and locusts should be provided, although the student by this time should be familiar with the structure of the locust. The lobster is much larger and easier to work than the crayfish, and instructions here given will apply to either. Both the lobster and the crayfish may be obtained from any of the natural-history supply companies. Crayfish may be collected in many sections of the country from streams and ponds, and should be preserved in the same manner as recommended for the locust. Material for Exercise 17 (the sow-bug) can be obtained in abundance under boards and stones and in other damp locations. It may be preserved in alcohol.

Exercise 12. *Comparison of the anatomy of the crayfish and the locust.* With the two specimens at hand, write out a careful comparison of the following points:

1. Nature of the body covering.
2. General divisions of the body. (A fusion of the head and thorax is known as the cephalothorax.)

Exercise 13. *The head and head appendages.* Remove the appendages from one side of the crayfish, beginning with the first appendage anterior to the first walking leg. These may be removed by grasping them near their attachment with a pair of strong forceps, and pulling them backwards toward the posterior end of the body. As each one is removed, it should be laid on a piece of wet blotting paper in regular order. The appendages of the crayfish are numbered from the anterior to the posterior end of the body. The head appendages are as follows:

1. The antennule, consisting of a basal piece and two long, slender filaments.
2. The antenna, consisting of a basal piece, one long, slender filament, known as the endopodite, and a short, platelike projection, known as the exopodite.
3. The mandibles.

4, 5. The first and second maxillæ. The above include all the head appendages. Write out a careful comparison of these appendages and corresponding appendages in the locust. Also with a hand lens make a comparative study of the eyes.

Exercise 14. *A comparison of the thoracic appendages.* Appendages 6, 7, and 8 of the thorax are known as the first, second, and third maxillipeds, and the appendages from 9–13 are the walking appendages. Write out a comparison of the thoracic appendages, noting the number, segmentation, etc.

Exercise 15. *A comparative study of the abdomens of the crayfish and locust.* Appendages 14–20 of the crayfish are known as the swimmerets. Compare these with the more anterior appendages of the crayfish. Also write out a careful comparison of the segmentation of the abdomens of the crayfish and locust.

Exercise 16. Make a drawing of the side view of the crayfish, naming the different appendages and divisions of the body.

Exercise 17. Make drawings of appendages 2, 10, and 16.

Exercise 18. *Comparison of the locust and sow-bug.* Write out a careful comparison of these two forms, noting:

1. The nature of the body covering.
2. The general divisions and segmentation of the body.
3. The nature of the appendages.
4. The number and position of the appendages.

Exercise 19. Make a drawing of the ventral view of the sow-bug, showing the number, position, and arrangement of the appendages.

Section VII. Comparison of Insects and Myriapoda (Types, Locust and Centipede)

Material. Centipedes are flattened, wormlike animals living under logs, stones, and other damp localities. They are quite common in most places, and may be collected and preserved in 75 per cent alcohol. Large specimens may usually be supplied by most of the natural-history supply houses.

Exercise 20. Write out a detailed comparison of a centipede and locust, noting the following points:

1. The general divisions of the body.
2. The nature of body covering.
3. The segmentation of the body.
4. The eyes and antennæ.
5. The mouth-parts.
6. The legs, number of their segments, etc.

Exercise 21. Make a drawing of the dorsal view of the head.

Exercise 22. Make a drawing of a ventral view of the head.

Section VIII. Comparison of Insects and Arachnida (Types, Spider (*Argiope*) and Locust)

Material. When possible, the ladder-spider should be collected for this work, as it is large, brilliantly colored, and can usually be collected in large numbers in the fall.

Exercise 23. Write out a careful comparison of the following parts:

1. The covering of the body and segmentation.
2. The general divisions of the body.
3. The eyes (located on the anterior portion of the cephalothorax), their number, arrangement, etc.
4. The mouth-parts, consisting of the mandibles, with terminal fang, maxillæ, hypopharynx, and a rudimentary labium.
5. The legs, number, number of segments, etc.
6. The abdomen, including the following structures:
   a. The opening of the book-lungs, which lie on either side of the median line at the anterior end of the abdomen and are respiratory in function.
   b. The genital opening, situated in the female on a prominent median tubercle located between the book-lungs.
   c. The spinnerets, consisting of six papillæ at the posterior end of the body.

Exercise 24. Make a drawing of a dorsal view of the spider.

Exercise 25. Make a drawing of the mandibles and maxillæ of the spider.

CHAPTER XVIII

A COMPARISON OF DIFFERENT TYPES OF INSECTS; STRUCTURE OF THE BEE, FLY, AND BEETLE

Section IX. Anatomy of the Honey-Bee (Second Type of the Class Insecta)

Material. The ordinary honey-bee can be easily collected for this work, and should be in as fresh a condition as possible. While alcoholic specimens will do, it is much better to furnish the students with fresh material, or to dry the specimens and place them in a moist chamber about two hours before using. It is almost imperative that the students be supplied with prepared slides of the legs to supplement the dry material. As this section's work will not deal with the mouth-parts, prepared slides of these will not be needed until later.

1. General anatomy of the honey-bee. The bee furnishes an excellent example of the specialization of insects, all of the parts being modified for a special purpose. This laboratory section's work is intended to give the student an idea of these modifications, with the exception of the mouth-parts, which will be studied later. The plan of structure does not differ much from that of the locust; the student, however, should notice the following points:

Exercise 26. Write out a careful comparison of the bee and locust as follows:

1. The nature of the body covering.
2. The segmentation of the body.
3. The divisions of the body.
4. The number and position of the appendages.
5. The structure of the head (except the mouth-parts). Note the compound eyes, ocelli, and antennæ.

2. Modifications of the prothoracic leg. Carefully remove the prothoracic legs and mount in the glycerin solution. Compare with the prepared slides and notice the following points (the general divisions of the leg are the same as those of the locust):

a. *The coxa.* This basal piece is a rather large, triangular segment attached to the prothorax.

b. *The trochanter.* This is proportionally larger than in the locust; aside from this it shows no special modifications.

c. *The femur.* This is a large, club-shaped joint covered with long hairs.

d. *The tibia.* This segment is smaller than the preceding and is provided with a spine at the lower end.

e. *The tarsus.* The tarsus consists of five segments, the first being nearly as large as the tibia. It is provided with a notch, near its attachment to the tibia, which, together with the spine on the latter segment, forms the antenna cleaner.

Notice also the bilobed claws on the end of the tarsus, together with the median, flaplike structure known as the empodium. This secretes a sticky substance, which enables the bee to walk on a smooth surface.

Exercise 27. Make an enlarged drawing of a prothoracic leg, showing the segmentation, antenna cleaner, claws, etc.

3. Mesothoracic leg. The mesothoracic leg differs but slightly from the prothoracic leg, except that the antenna cleaner is absent and that on the inner side of the tibia there is a spur used in loosening the pollen from flowers.

Exercise 28. Make drawing of the inner side of the tibia and tarsus of the mesothoracic leg, showing the spine.

4. Metathoracic leg. This resembles the prothoracic leg, with the following modifications:

a. *The pollen-basket.* The outer surface of the tibia of the third thoracic leg is smooth and surrounded with a row of long, incurved hairs. This is known as the pollen-basket, and is used in carrying the pollen to the hive.

b. *The wax pincers.* Between the end of the tibia and the tarsus is a pincerlike structure consisting of a row of thick, flattened spines on the edge of the tibia, which come in contact with the smooth edge of the tarsus. These wax pincers are supposed to be used in removing the plates of wax from the abdomen, where they are secreted.

c. *The pollen comb.* This structure is located on the inner surface of the flat, basal segment of the tarsus, and consists of nine parallel rows of bristles, which are used in combing the pollen from the body, where it collects while the bee is gathering nectar.

Exercise 29. Make a drawing of the inner surface of the third thoracic leg.

Exercise 30. Make a drawing of the outer surface of the third thoracic leg.

Exercise 31. Examine the wings of the bee under the compound microscope and make a drawing showing the fine hooks and groove by means of which the wings are locked together during flight. Also notice the arrangement of the veins.

Section X. Comparison of the Fly with the Locust and Bee

Material. Probably the best material for the study of the anatomy of the Diptera is some of the large horse-flies, like *Tabanus atratus*, although these may be hard to secure in sufficient numbers. If these cannot be secured, any of the smaller, more abundant species will suffice. The material may be preserved in 75 per cent alcohol, or dried, the latter method probably being preferable for a study of the external parts; the specimens should, however, be placed in a moist chamber at least twenty-four hours before they are wanted for use.

Exercise 32. Write out a careful comparative description of the external anatomy of the fly, comparing it with the locust and the bee, and noting the following points of structure:

1. The divisions of the body, the body covering, and the segmentation.
2. The head and its appendages, with the exception of the mouth-parts.
3. The thorax and thoracic appendages.
4. The abdomen and its segmentation.

Exercise 33. Make a drawing of the wing of a fly, comparing it with the text figure.

Section XI. Comparison of a Beetle with the Locust and the Bee

Material. Almost any of the larger beetles will serve for this work, although the May-beetle will probably be the easiest to secure. These should be preserved in the alcohol-glycerin solution.

Exercise 34. Write out a comparison of the beetle with the locust and bee, noting:

1. The nature of the body covering, the segmentation, and the divisions of the body.
2. The head, including the eyes and antennæ.

(If time permits, the mouth-parts of the beetle might profitably be dissected and compared with those of the locust.)

3. The thorax, including the wings and wing-covers, especially noting the modification of the wing-covers.
4. The abdomen, the number of segments, etc.

Exercise 35. Make a drawing of the antennæ, wings, and wing-covers of the beetle.

CHAPTER XIX

THE INTERNAL ANATOMY OF THE LOCUST

SECTION XII

Material. Fresh material will be found the most satisfactory for this work, the specimens being placed in 85 per cent alcohol for about an hour before being used. If fresh material is not available, alcoholic specimens that have been previously soaked in warm water for a short time will work very satisfactorily. After removing the wings and legs from the right side of the locust, make a longitudinal, dorsal incision to the right of the median, dorsal line, and the entire length of the body. Make a similar longitudinal ventral incision to the right of the midventral line. Remove carefully the right side of the chitinous covering, exposing all of the internal organs, of which the following systems should be studied:

1. Digestive system. The digestive system occupies the greater part of the thoracic and the ventral part of the abdominal cavity. It is essentially a continuous tube, divided into the following regions, each with a particular function to perform.

a. *The esophagus.* This is a cylindrical tube, with tough, muscular walls. It runs from the mouth, opening dorsally to a point opposite the foraminal aperture, where it bends at right angles and enters the thorax.

b. *The crop.* This is an enlargement of the esophagus and, beginning in the mesothorax, runs to the abdomen, almost filling the mesothoracic and metathoracic cavities.

c. *The gizzard* (*proventriculus*). This is the next division (not found in the genus *Acridium*). The walls are thick and muscular, and on the inside are lined with a series of chitinous plates which are used in completing the mastication of the food.

d. *The stomach* (*ventriculus*). This division is separated from the gizzard by a slight constriction. It is of approximately the same diameter as the gizzard and extends from the first to the seventh segment of the abdomen.

e. *The large intestine.* This is of somewhat smaller diameter than the stomach and runs from the seventh to the tenth segment.

f. *The small intestine.* The small intestine is a short, muscular tube running from the end of the large intestine toward the dorsal part of the body and ending in segment eleven.

g. *The rectum.* The rectum is a short, muscular enlargement in segment eleven and ends in the anal opening.

2. Accessory organs of digestion. In connection with the alimentary tract are a certain number of glands or glandular structures which either aid in the digestion of the food or assist in eliminating the waste products.

a. *The salivary glands.* These are small, white glands located on either side of the esophagus in the thorax. They open out into two main ducts which lead to the mouth.

b. *The gastric cæca.* The gastric cæca consist of a set of eight double, cone-shaped pouches which open at the union of the crop and stomach. They form a complete belt around the alimentary tract at this point and secrete a fluid which aids in digestion.

c. *The Malpighian tubules.* The Malpighian tubules are a system of very fine, hairlike tubes which arise from the most anterior end of the large intestine. Their function is excretory, similar to that of the kidneys.

3. Reproductive system. The ease with which the organs of this system may be distinguished depends considerably on the sex and the time of year at which the specimens were collected.

a. *Female reproductive organs.* In the fall, just before the eggs are deposited, the entire abdomen of the female is filled with a yellow, coarsely granular organ known as the ovary. There are a pair of these, one located on either side of the body. Running from the posterior end of the ovary are two small tubes called the oviducts, which unite near the posterior end of the body to form the vagina. This opens externally upon the upper surface of the subgenital plate, between the ovipositor. On a median line slightly dorsal to the egg guides there is a second opening, which communicates with a long, slender tube ending in an enlarged pouch known as the spermatheca. This entire structure is very difficult to locate.

b. *Male reproductive organs.* The general arrangement of the male reproductive organs is quite similar to that of the female, only much smaller. The two pair of testes (corresponding to the ovaries) lie on the dorsal side of the stomach and are inclosed in a saclike

membrane. Leading from the testes are two very fine, hairlike tubes known as the vas deferens. These pass down to the ventral side of the body on either side of the alimentary tract and unite, forming the ejaculatory duct, which opens dorsally to the subgenital plate. Just before the union of the vas deferens they are joined on either side by a number of fine tubules known as the seminal vesicles, the function of which is to store up the products of the reproductive glands.

Exercise 36. Make a careful drawing of the side view of a locust, showing the alimentary tract, accessory organs of digestion, and either the male or the female reproductive system.

4. Nervous system. With a pair of fine scissors cut the alimentary tract through the esophagus and small intestine, and carefully remove, together with the reproductive organs. Great care must be taken to not injure or displace any of the other organs. Also carefully remove the right side of the chitinous portion of the head.

The nervous system consists principally of a supra-esophageal ganglion, or brain, which lies dorsal to the esophagus. This is a large, whitish mass of nervous tissue and, if carefully dissected, can be seen to be directly connected with the compound eyes. Running on either side of the esophagus is a small, white nerve cord that unites on the ventral side, forming the sub-esophageal ganglion. Running from this ganglion toward the posterior end of the body is the ventral nerve cord. If carefully examined, this will be found to consist of two parallel white cords that are occasionally united by the ventral ganglia, from which arise numerous lateral nerves. These ventral ganglia occur in the following segments, — the prothorax, mesothorax, metathorax, and abdominal segments two, three, five, six, and seven.

5. Muscular system. In elementary work of this sort no attempt will be made to trace out the different sets of muscles, but the general relation of the different muscles to the segments should be noted. In the mesothorax and metathorax notice the large wing muscles; also in the abdomen notice the longitudinal and ventral bands.

6. Respiratory system. The respiratory system is made up of tubes known as tracheæ. These open out along each side of the body; the openings, which have already been noted, are termed the

spiracles. Soon after entering the body the tracheæ unite to form two large lateral trunks. From these, dorsal branches are given off, which unite, forming two parallel dorsal trunks. Running off from both the dorsal and lateral trunks are smaller branches, which separate into extremely minute tubes and ramify through all the tissues.

Exercise 37. If fresh specimens are at hand, mount in water some of the fatty tissue surrounding the alimentary tract, and examine under the compound microscope. The tracheæ will be seen as much-branched silver-colored tubes. Make a careful drawing.

Exercise 38. Make a drawing of the side view of the locust, with the alimentary tract and reproductive organs removed, showing the general arrangement of the muscular, tracheal, and nervous systems.

7. Circulatory system. The circulatory system consists of a dorsal, median, tubular heart. This can be seen in fresh specimens by removing the dorsal body wall.

Exercise 39. In order to observe the rhythmic contraction of the heart, obtain living larvæ of mosquitoes, dragon-flies, or May-flies. Place them in water on a slide and examine under the microscope. Draw.

CHAPTER XX

MOUTH-PARTS OF INSECTS

The type of biting mouth-parts has already been considered in Chapter XVI, the forms here considered being more highly specialized.

SECTION XIII. SUCKING MOUTH-PARTS (TYPE, SQUASH-BUG)

Material. Students should be provided with prepared slides of the mouth-parts of the squash-bug. They should also have alcoholic specimens, as the arrangement of the parts cannot be easily distinguished on the prepared slides. Before studying the prepared slides the students should dissect out the mouth-parts of an alcoholic specimen. With a pair of sharp-pointed scissors cut off the ventral part of the head and place it in a thick glycerin solution, consisting of equal parts of glycerin and alcohol. Then, under the lens of a dissecting microscope, pull the long proboscis apart, noting the order of arrangement of the different pieces.

The mouth-parts of the squash-bug consist of a long, jointed beak in which are found four long, threadlike setæ. They should be compared with the mouth-parts of the locust.

1. **Labrum.** The labrum, or upper lip, is a long, triangular, sharply pointed piece, with slightly serrated edge, and fits over the groove of the lower lip.

2. **Mandibles.** The mandibles are a pair of long, hairlike setæ with sharp-toothed points. They adhere very closely together, and are used in cutting into the tissues of plants in order to induce a flow of sap.

3. **Maxillæ.** These closely resemble the mandibles and, like them, lock together, forming a lancelike structure. They are used in piercing plants, the same as the mandibles.

4. **Labium.** The labium, or under lip, is formed into a long, partially closed tube, in which lie the mandibles and maxillæ. It is made up of four segments of about equal length.

Exercise 40. Make a careful drawing of the mouth-parts of the squash-bug, showing the above details.

Section XIV. Specialized Piercing Mouth-Parts (Type, Horse-fly)

Material. Specimens of any of the common horse-flies (*Tabanus*) will do for this work, though only female flies can be used, as the mandibles are lacking in the males. The two sexes may be distinguished by the position of the eyes. In the male the eyes touch for a greater or less distance, while in the female there is a narrow space between the eyes. The mouth-parts are quite conspicuous and should be removed and mounted as in the previous section. Students should also be provided with prepared slides. A comparison should be made with the mouth-parts already studied. The mouth-parts of the fly are more highly specialized than those of the squash-bug, and consist of a number of stylets, or flat, pointed pieces, more or less completely inclosed in the fleshy under lip. They consist of the following parts:

1. Labrum. The labrum, or upper lip, is the uppermost stylet, and consists of a flat, unpaired piece, bluntly tipped. It is broader than any of the remaining stylets.

2. Mandibles. These consist of a pair of flat, smooth, sharply pointed pieces adapted for piercing.

3. Maxillæ. These are the second pair of stylets and are underneath the mandibles, which they very closely resemble. The maxillæ are narrower than the mandibles, are less strongly chitinized, and are provided with palps, which are attached to the base of each maxilla. The palps consist of two segments and are thick, clublike structures covered with very fine hairs.

4. Hypopharynx. The hypopharynx, or tongue, is a slender, unpaired piece resembling very much the labrum, but is narrower and more sharply pointed. It lies directly underneath the maxillæ.

5. Labium. This is a conspicuous, proboscislike structure, which partially incloses the other mouth-parts. At the end of the labium is a large, fleshy, disklike piece called the labella. It consists of two lobes, which fit closely around the stylets when they are being used.

Exercise 41. Make careful drawings of the above mouth-parts.

Section XV. Sucking Mouth-Parts (Type, Butterfly)

Material. The commonest type, and one of the best for this work, is the monarch butterfly (*Anosia plexippus*). These may be collected and dried and the scales carefully removed from the head with a stiff camel's-hair brush. Part of the specimens should be boiled in caustic potash (KOH) and the head mounted in balsam. The remainder of the specimens should be placed in the moist chamber for a day or so before they are wanted. The mouth-parts of the Lepidoptera are greatly modified, and only careful study reveals the relation between them and the biting mouth-parts of the locust.

1. Labrum. This is a very short, quadrangular piece, almost or entirely indistinguishable in some species, as it is immovably joined to the clypeus.

2. Mandibles. The mandibles are almost entirely wanting in the monarch butterfly, although they are represented in some forms by two triangular pieces which are of little or no use to the insect. In some of the moths they are more highly developed.

3. Maxillæ. The maxillæ are the most conspicuous part of the mouth, the two together forming a long, coiled sucking tube used in drawing up nectar. Each maxilla is deeply grooved on the inner side, the two fitting together, forming a complete tube. The maxillary palps are wanting in this form, although present in some of the lower forms.

4. Labium. The labium consists of a small, triangular flap almost completely fused with the base of the maxillæ. Extending out from either side of the labium are the large labial palps, which form two prominent, plumelike projections from either side of the head. They are three-jointed and covered with scales.

Exercise 42. Make a drawing of the mouth-parts of the monarch butterfly, showing the above in detail.

Section XVI. Sucking and Biting Mouth-Parts (Type, Honey-bee)

Material. The honey-bees for this section's work may be preserved in 75 per cent alcohol. It may be found advantageous to substitute the bumble-bee, as the mouth-parts are larger and more easily dissected. In either case it is desirable that the students be provided with prepared slides. The mouth-parts

of the honey-bee are made up of the typical number of parts, but are adapted both for biting and sucking. The student should refer to the other types of mouth-parts already studied.

1. Labrum. This consists of a small, rectangular piece attached to the clypeus, and resembles closely the labrum of the locust.

2. Mandibles. These are hard, well-developed structures, more elongated than in the locust, and are devoid of teeth.

3. Maxillæ. The maxillæ are complicated structures and, as in the locust, consist of the following parts:

a. *The cardo.* This serves as the attachment to the epicranium and is an elongated piece.

b. *The stipes.* These are rather thick, club-shaped pieces strongly chitinized.

c. *The maxillary palps.* These are short and almost atrophied, located at the distal, outer edge of the stipes.

d. *The lacinia galea.* These two structures are fused together in the bee and form a pair of elongated pieces deeply grooved on the inner edge. When fitted together, they form a partially closed tube more or less completely surrounding the parts of the labium.

4. Labium. The labium, or under lip, is even more modified than the maxillæ, and consists of the following parts:

a. *The submentum.* This is a triangular, basal piece, running off from which are two small, rodlike pieces known as the lora.

b. *The mentum.* This is a large, pear-shaped piece attached to the submentum.

c. *The labial palps.* The labial palps are greatly modified, forming two long, four-jointed structures grooved on the inner edge. When these are fitted together, they form a tube which in turn is inclosed by the lacinia galea of the maxillæ.

d. *The paraglossa.* This is a sheathlike arrangement which incloses the base of the tongue, lies median to the palps, and is attached to the mentum.

5. Tongue. The tongue is a long, flexible rod, densely covered with hairs. Along the ventral side there is a deep groove, forming almost a complete tube, and at the end is a flaplike structure known as the flabellum.

Exercise 43. Make a careful drawing of the mouth-parts of the honey-bee, showing the above structures in detail.

CHAPTER XXI

THE LIFE HISTORY OF INSECTS

SECTION XVII. LIFE HISTORY OF A PLANT-LOUSE (FAMILY APHIDIDAE)

Material. The family *Aphididae* probably furnishes some of the best examples for the study of incomplete metamorphosis of insects. It does not matter much what particular species is selected for this work, as any of the ordinary aphids attacking greenhouse plants will be found quite satisfactory. Among the forms most easily managed may be mentioned the lettuce aphis and the rose aphis. These may almost always be secured at any time of year. For work on the lettuce aphis each student should be provided with a flowerpot in which is growing one small lettuce plant. The instructor should keep on hand a supply of aphids. These should be grown on lettuce under a large bell jar, to prevent the escape of the winged forms. Each student should be given one wingless, viviparous female just before the insect reaches maturity.

It will be recalled that the life history of the *Aphididae* may vary considerably with the different species. Nearly all of them, however, have two forms of reproduction, known as viviparous reproduction (in which the living young are brought forth without the fertilization of the female by the male) and oviparous reproduction (in which eggs are deposited by fertilized females). The sexual forms are usually brought forth in the fall by a viviparous female, and after mating, the oviparous female deposits eggs which are not hatched until the next spring. From these eggs are hatched the viviparous females, this form of reproduction continuing throughout the summer. It will also be recalled that of the viviparous forms part may be winged and part wingless.

Exercise 44. Watch the viviparous female carefully and write up a detailed set of notes, including the following observations:

1. Date of birth of first young, giving the hour when the observation was made.
2. Date of birth of subsequent young, giving the number of young, the day, and the hour when observed. Be sure that only one viviparous female is present on each culture, and keep careful track of all the offspring.

3. Number the offspring consecutively, according to age, and note which developed into winged and which into wingless forms.

4. Note the age at which each of these individuals begins reproduction. It might be suggested that when the first of this generation begins reproducing, it is best to remove the young in order to prevent confusion of the generations.

Exercise 45. Make a chart from your above notes, giving the number of the individual, whether winged or wingless, date of birth, date of maturity (when first young is produced).

Exercise 46. Notes on the rapidity of growth. Isolate some newly born individuals, noting the date and hour of birth. Watch these carefully, and note the date and the hour that molting occurs. The cast skin will usually be found near the young aphids, which begin feeding soon after molting. Those individuals just having molted will be found to be the lightest in color, but the cast skin should be taken as the only proof that the insect has molted. As soon as these individuals begin to reproduce, tabulate your above notes, giving the number of hours between each molt for each individual.

Exercise 47. Write up a detailed set of notes describing one wingless individual after each molt, up to and including the adult form, noting all the changes which may occur.

Exercise 48. Write up a detailed set of notes, similar to the above, for the winged form.

Exercise 49. Mount a wingless individual in the alcohol-glycerin solution and make a drawing of the dorsal view. (The aphids should first be dipped in 95 per cent alcohol, and may then be mounted directly in the glycerin solution.)

Exercise 50. Mount a winged individual in the alcohol-glycerin solution and make a drawing of the dorsal view.

Section XVIII. Life History of the Dragon-Fly

Material. It will be quite impractical for a class in elementary entomology to try to trace the complete life history of the dragon-fly, but this form will give the student a good idea of the habits and structure of aquatic nymphs. The dragon-flies deposit their eggs on water plants, and as soon as these hatch, the young nymphs settle to the bottom of the pond and may be found, at almost any time of the year, crawling about in decaying vegetation or other sediment. The easiest way to secure them is to rake out the sediment from the quiet pools of a stream, or from the edge of ponds, with an ordinary garden rake. The nymphs, together with a small amount of sediment, should be placed in an aquarium until ready for observation. This applies especially to material collected in the fall, as it will be difficult for each individual student to provide food and suitable conditions for the nymphs that he may have under his observation.

When this work is undertaken by a class, each student should be provided with a glass dish containing three or four of the largest-sized nymphs. As it is necessary to feed the nymphs on other aquatic insects, it might be better not to collect the material until early spring.

Exercise 51. *Observations on the structure of the nymphs.* Write up a careful description of the nymphs, noting the details of structure. In the description, refer to and use the terms with which you have already become familiar in your description of other forms.

Exercise 52. *Habits of the nymphs.* Make as many notes as possible on the general habits of the nymphs, noting their methods of feeding, locomotion, secreting themselves, etc. (see page 98).

Exercise 53. *Observations on the transformation of nymphs.* Note carefully whether or not the nymph molts, or sheds its skin, and, if observed, how the act is performed. Toward spring the nymphs should be placed in the sunlight as much as possible. Each dish should also be provided with a number of sticks, up which the nymphs may crawl when they are ready to transform to the adult stage. If possible, observe this transformation and write up a complete set of notes on the subject.

Section XIX. Complete Metamorphosis. Life History of the Cabbage Butterfly (*Pontia rapae*)

Material. The following instructions have been prepared especially for the study of the cabbage butterfly, though the life history of any of the other Lepidoptera may be studied in the same manner, substituting, of course, the proper food plants. Each student should be provided with a flowerpot in which is growing a young cabbage plant. If this work may be begun by the middle of September, cabbage butterflies should be collected and one pair placed in each of a number of breeding cages (see Chapter XXIII). The pots containing the young plants can be placed in the cages, and daily observations made for the presence of eggs. After the eggs hatch, a large lantern globe, the top of which has been covered with cheesecloth, should be placed over each plant, to prevent the escape of the larvæ.

Exercise 54. *Egg deposition.* The student should, if possible, determine and make notes of the following points:

1. On what part of the leaf are the eggs deposited?
2. Are they deposited in clusters or singly?
3. The number of eggs deposited by one female.
4. The period of incubation.
5. Describe and make drawings of the eggs.

Exercise 55. *Observations on the larvæ.* Determine and make notes of the number of molts, describing each of the larval stages.

Exercise 56. *Observations on the pupæ.* If possible, observe the transformation of the larvæ to the pupal form. Note the locality selected for pupation, the attachment of the pupa, and length of time in the pupal stage. Also draw and describe. (After pupation the pupæ should be removed to a cool, dark place and left until spring, or, if wanted for more immediate use, they should be placed in a light, warm room, where they will probably emerge in a short

time. Low temperatures are not injurious, but too much moisture must be avoided. The latter part of March the pupæ may be brought out and again placed under observation.)

Exercise 57. *The emergence of the adult.* Note the date and the method of emergence, and write a brief description of the adult.

Section XX. Complete Metamorphosis. Life History of the Fruit-Fly (*Drosophila* sp.)

Material. Material for this work may be secured by placing decaying bananas in the sunlight for a few days. The material should then be covered with a bell jar and used as a stock culture. Each student should be provided with a glass tumbler containing about one fourth of an inch of decayed banana. Cut a piece of black paper the size of the tumbler and lay on top of the banana, and cover the tumbler securely with a glass plate. The student should then place three or four adult fruit-flies in the tumbler.

Exercise 58. Write up a careful set of notes on the following points:

1. Describe, and make a drawing of egg, which will be deposited on the black paper.
2. Note the length of time of incubation.
3. Describe, and make a drawing of a larva.
4. If possible, determine the length of the larval stage.
5. Describe, and make a drawing of a pupa.
6. Determine the length of the pupal stage.
7. Describe the adult, and determine the distinguishing characters of the sexes.

CHAPTER XXII

CLASSIFICATION OF INSECTS

Section XXI. Classification of the Orders of Insects

Material. One of two methods may be employed for this work: (*a*) Each student should be required to make a collection of insects containing representatives of at least eight of the principal orders. (*b*) Provide each student with a representative collection of twenty-five insects. These should be numbered from one to twenty-five, and should contain as nearly representative forms as possible.

Exercise 59. On a sheet of paper place the numbers one to twenty-five. After each number write the order (to be determined by the key) to which the corresponding insect belongs.

Section XXII. Classification of Families

Material. Give each student a collection representing as nearly as possible the different families of insects treated in the key. It will be found convenient to place twenty-five insects on a block, each block containing only the insects of one order, thus obviating the necessity of classifying every insect to its order before placing it in the family. The insects should be distributed as follows: One block containing representatives of the lower orders (Neuroptera and Neuropteroid insects); one block of Hemiptera; two of Coleoptera; two of Lepidoptera; one of Hymenoptera; and one of Diptera.

Exercise 60. Classification of the families of the lower orders.

On a sheet of paper place the numbers one to twenty-five. After each number write the family (to be determined by the key) to which the corresponding insect belongs. If possible, by referring to the text or by comparison with a named collection, identify common forms to genus and species.

Exercise 61. Classification of the families of Hemiptera.
Exercise 62. Classification of the families of Coleoptera.
Exercise 63. Classification of the families of Coleoptera.
Exercise 64. Classification of the families of Lepidoptera.
Exercise 65. Classification of the families of Lepidoptera.
Exercise 66. Classification of the families of Hymenoptera.
Exercise 67. Classification of the families of Diptera.

KEY TO THE ORDERS OF INSECTS

The principles underlying the classification of insects have already been discussed in the text. In arranging this key an attempt has been made to eliminate all useless characters and to include only those families commonly encountered. Possibly this elimination has been carried too far for some of the extreme forms of the different orders; however, in an elementary textbook it is not deemed practical to include material that would be of use only to the specialist.

Several families are included in the key which are not mentioned in the text. This becomes necessary for the complete arrangement of the key, and may be of use in aiding students to determine the more uncommon families which they may collect. In giving out specimens for determination the teacher should, if possible, use only those families described in the text.

The following key is intended only for the identification of typical adult forms. An attempt has been made to produce a usable key in preference to a strictly natural one. An ideal key should, of course, combine these two characteristics, but it has been found necessary many times to sacrifice the natural arrangement for clearness.

In the production of these keys the authors are indebted to all previous workers in entomology. Due credit is given in every case where a key has been adapted from another author's work.

KEY TO THE ORDERS

A. Mouth-parts adapted for biting.
- *B.* Without wings, or rudiments of wings.
  - *C.* Mouth-parts retracted within the head. (Page 73) . . APTERA
  - *CC.* Mouth-parts not retracted within the head.
    - *D.* Abdomen joined to thorax by slender petiole. Ants. (Page 243) . . . . HYMENOPTERA
    - *DD.* Abdomen broadly joined to thorax.
      - *E.* Insects small, body antlike or louselike in form. Bird-lice; book-lice; white ants. (Page 103) . . . PLATYPTERA
      - *EE.* Insects of medium or large size. Body not antlike or louselike in form.
        - *F.* Head prolonged into beak, at the end of which are the biting mouth-parts. Scorpion-flies. (Page 93) MECOPTERA
        - *FF.* Head not prolonged into beak.

G. Antennæ filiform. Cockroaches; grasshoppers; walking sticks. (Page 76) . . . ORTHOPTERA

GG. Antennæ serrated, or of various types, but not filiform. Fireflies, etc. (Page 136) . . COLEOPTERA

BB. Winged insects.

C. First pair of wings horny, meeting in a straight line down the back.

D. Abdomen with forceplike appendages. Earwigs. (Page 87) EUPLEXOPTERA

DD. Abdomen without forceplike appendages. (Page 136) COLEOPTERA

CC. First pair of wings leathery or membranous.

D. Wings membranous; the second pair, if present, not folded in plaits under first.

E. Head prolonged into beak, at the extremity of which are the biting mouth-parts. Scorpion-flies. (Page 93) MECOPTERA

EE. Head not prolonged into beak.

F. Wings with but few cross veins. (Page 243) HYMENOPTERA

FF. Wings net-veined; abdomen broadly joined to thorax.

G. Abdomen provided with two or three long, many-jointed filaments. (Page 95) . . EPHEMERIDA

GG. Abdomen without jointed filaments.

H. Antennæ short, awl-shaped, and inconspicuous; wings of equal size, held horizontal, vertical, or parallel to the body; not rooflike. Dragon-flies. (Page 98) . . . . ODONATA

HH. Antennæ not awl-shaped, more or less prominent.

I. Wings folded flat on body. Body compact, antlike, and flattened or louselike in form. PLATYPTERA

II. Wings rooflike over body; body linear. (Page 90) . . . . NEUROPTERA

DD. First pair of wings more or less leathery, with second pair folded under first.

E. Wings clothed with hairs. Caddis-flies. (Page 93) TRICHOPTERA

EE. Wings not clothed with hairs.

F. First pair of wings leathery, second membranous. Not alike in structure. (Page 76) . . . ORTHOPTERA

FF. Wings alike in structure, both more or less leathery.

G. Tarsi 5-jointed. (Page 90) . . . . NEUROPTERA

GG. Tarsi less than 5-jointed. Stone-flies. (Page 97) PLECOPTERA

AA. Mouth-parts adapted for sucking.
B. Mouth-parts not adapted for piercing.
C. Body covered with scales, wings usually broad. Butterflies and moths. (Page 172) . . . . LEPIDOPTERA
CC. Body not covered with scales, wings comparatively narrow.
D. Mandibles, if present, not fitted for biting.
E. Two pairs of wings fringed with hair. Thrips. PHYSOPODA
EE. One pair of wings, usually naked or with microscopic hairs. Flies. (Page 218) . . . . DIPTERA
DD. Mandibles normally developed . . . . . HYMENOPTERA
BB. Mouth-parts adapted for piercing.
C. Mouth-parts consisting of a jointed tube containing the bristlelike mandibles and maxillæ. Bugs. (Page 107) . . . HEMIPTERA
CC. Mouth-parts consisting of a fleshy tube containing usually bristle-like mandibles and maxillæ.
D. Wingless insects; body laterally compressed. Fleas. (Page 240) SIPHONAPTERA
DD. Winged or wingless insects, body not laterally compressed.
E. Tarsus provided with single strong, hooklike claw. Wingless parasitic lice of mammals. (Page 107). HEMIPTERA
EE. Tarsus normal. Winged or wingless insects. (Page 218) DIPTERA

KEY TO THE FAMILIES OF APTERA[1]

A. Abdomen elongate, composed of at least ten segments; antennæ many-jointed; abdomen usually provided with a pair of two-or-more-jointed, filamentous, or forceplike appendages. (Page 74) Suborder I, THYSANURA
B. Body covered with scales . . . . LEPISMIDAE
BB. Body not covered with scales.
C. Abdomen without caudal appendages . . . . ANISOPHAERIDAE
CC. Abdomen with caudal appendages.
D. Caudal appendages sickle-shaped . . . . . . JAPYGIDAE
DD. Caudal appendages consisting of many-jointed filaments. CAMPODEIDAE
AA. Abdomen composed of not more than six segments; antennæ of not more than eight segments; ventral spring usually present, but no terminal abdominal appendages. Springtails. (Page 74) Suborder II, COLLEMBOLA
B. Ventral spring present.
C. Ventral spring attached on penultimate abdominal segment.
D. Abdomen globular, only slightly longer than broad. SMINTHURIDAE
DD. Abdomen cylindrical, longer than broad. ENTOMOBRYIDAE

[1] Revised from Dr. K. W. v. Dalla Torie's "Die Gattungen und Arten der Apterygogenea."

CC. Ventral spring attached to antepenultimate abdominal segment. PODURIDAE

BB. Ventral spring absent . . . . APHORURIDAE

THE EPHEMERIDA

This order includes only a single family, the members of which have delicate membranous wings with a fine network of veins. The fore-wings are large, and the hind-wings much smaller or wanting. Mouth-parts rudimentary. May-flies. (Page 95) . . . . EPHEMERIDAE

KEY TO THE FAMILIES OF ODONATA[1]

A. Front and hind wings similar in outline, distinctly narrow at base, held vertically over the back when at rest. Damsel-flies. (Page 98) Suborder ZYGOPTERA

B. Wings with not less than five antecubital cross veins. CALOPTERYGIDAE

BB. Wings with not more than three, usually two, antecubital cross veins. AGRIONIDAE

AA. Front and hind wings dissimilar, the hind-wings being much wider at the base; wings held horizontally when at rest. Dragon-flies. (Page 98) Suborder ANISOPTERA

B. Antecubital cross veins of first and second rows usually meeting each other . . . . LIBELLULIDAE

BB. Antecubital cross veins of first and second rows not meeting each other.

C. Eyes meeting above in median line of head; abdomen with lateral ridges . . . . AESCHNIDAE

CC. Eyes separate, or nearly so; abdomen without lateral ridges.

D. Eyes touching at a single point, or barely apart. CORDULEGASTERIDAE

DD. Eyes distinctly separated . . . . GOMPHIDAE

THE PLECOPTERA

This order includes only a single family, having four membranous wings, the hind-wings being folded plaitlike under the fore-wings. The mouth-parts are biting, but slightly developed. Stone-flies. (Page 97) . . . PERLIDAE

KEY TO THE FAMILIES OF NEUROPTERA

A. Hind-wings broad at base, the inner margin folded in plaits. Dobsons. (Page 90) . . . . SIALIDAE

AA. Hind-wings narrow at base, not folded in plaits.

B. Prothorax greatly prolonged into necklike stalk.

[1] Revised from Kellogg's "American Insects."

C. Prothoracic legs normal . . . . RAPHIDIIDAE
CC. Prothoracic legs fitted for grasping . . . . . MANTISPIDAE
BB. Prothorax normal.
C. Wings clear, densely net-veined.
D. Antennæ filiform, without terminal knob. Lace wings. (Page 92) . . . . CHRYSOPIDAE
DD. Antennæ filiform, with terminal knob. Ant-lions. (Page 93) MYRMELEONIDAE
CC. Wings more or less opaque, with many longitudinal but few cross veins . . . . HEMEROBIIDAE

THE MECOPTERA

This order includes only one family, having four membranous wings, furnished with numerous veins. The head is prolonged into a beak, at the end of which are the biting mouth-parts. Scorpion-flies. (Page 93) PANORPIDAE

THE TRICHOPTERA

This order includes but one family, having four membranous wings, furnished with numerous longitudinal but few cross veins; wings more or less densely covered with hair; rudimentary biting mouth-parts. Caddis-flies. (Page 93) . . . . PHRYGANEIDAE

KEY TO THE PLATYPTERA

A. Body cylindrical, social insects with white, antlike bodies. White ants. (Page 103) . . . . TERMITIDAE
AA. Body depressed, if cylindrical, not antlike. Nonsocial, louselike insects.
B. Antennæ of not more than five segments. Bird-lice. (Page 106) Suborder MALLOPHAGA
C. Antennæ exposed, consisting of three or five segments.
D. With three-segmented antennæ; tarsi with one claw; infesting mammals only . . . . TRICHODECTIDAE
DD. With five-segmented antennæ; tarsi with two claws; infesting birds only . . . . PHILOPTERIDAE
CC. Antennæ concealed in shallow cavities on underside of head, consisting of four segments.
D. Tarsi with one claw; infesting mammals only . GYROPIDAE
DD. Tarsi with two claws; infesting birds only . . LIOTHEIDAE
BB. Filiform antennæ of more than five segments. Suborder CORRODENTIA
C. Wings well developed; ocelli present in addition to the compound eyes. Bark-lice. (Page 105) . . . . PSOCIDAE
CC. Wings and ocelli wanting. Book-lice. (Page 105) . ATROPIDAE

THE EUPLEXOPTERA

This order includes a single family the members of which have four wings: the first pair are leathery or horny, meeting in a straight line down the middle of the back; the second pair are membranous, with numerous radiating veins folded lengthwise like a fan and then crosswise under the first pair. Earwigs. (Page 87) . . . . FORFICULIDAE

KEY TO THE FAMILIES OF ORTHOPTERA

A. Third pair of legs not adapted for leaping.
- *B.* Body oval, dorsoventrally compressed. Cockroaches. (Page 77) BLATTIDAE
- *BB.* Body elongate, not dorsoventrally compressed.
  - *C.* First pair of legs fitted for grasping and holding their prey; pronotum longer than any of the other body segments. Praying mantis. (Page 78) . . . . MANTIDAE
  - *CC.* First pair of legs not fitted for grasping and holding prey; pronotum short. Walking-sticks. (Page 80) . . . . . . PHASMIDAE

AA. Third pair of legs adapted for leaping.
- *B.* Antennæ shorter than body. Locusts. (Page 81) . . . ACRIDIDAE
- *BB.* Antennæ longer than body.
  - *C.* Tarsi consisting of four segments. Long-horned grasshoppers. (Page 83) . . . . LOCUSTIDAE
  - *CC.* Tarsi consisting of three segments. Crickets. (Page 85) GRYLLIDAE

THE THYSANOPTERA

This order includes but a single family of very small insects with long, narrow, membranous wings, having but few or no veins and bordered by a fringe of long hair; the tarsi swollen, bladderlike, with or without claws. PHYSOPODAE

KEY TO THE FAMILIES OF HEMIPTERA[1]

A. Wingless insects with fleshy unjointed beak; parasitic on mammals. (Suborder PARASITICA.) Suctorial lice. (Page 121) . . PEDICULIDAE

AA. Winged or wingless insects, with a jointed beak.
- *B.* First pair of wings leathery at the base, membranous at the tip, the tips overlapping on the back; beak arising from front part of head. Suborder HETEROPTERA
  - *C.* Antennæ shorter than head. Aquatic or shore insects.
    - *D.* With two ocelli. Toad-bugs . . . . GALGULIDAE
    - *DD.* Without ocelli.

[1] Adapted from Kellogg's "American Insects."

E. Hind tarsus without claws.

F. Pronotum overlapping head above. Back-swimmers. (Page 108) . . . . NOTONECTIDAE

FF. Head overlapping prothorax above. Water-boatman. (Page 108) . . . . CORISIDAE

EE. Hind tarsus with claws.

F. Caudal end of abdomen furnished with a respiratory tube. Water-scorpions. (Page 109) . . . NEPIDAE

FF. Caudal end of abdomen without respiratory tube.

G. Hind legs flattened, adapted for swimming. Giant water-bug. (Page 109) . . . BELOSTOMATIDAE

GG. Hind legs slender, not adapted for swimming. NAUCORIDAE

CC. Antennæ at least as long as head.

D. Head as long as entire thorax . . . . . LIMNOBATIDAE

DD. Head shorter than thorax.

E. Last segment of tarsus more or less split, with claws inserted before apex.

F. Body elongated; beak four-jointed. Water-striders. (Page 109) . . . . HYDROBATIDAE

FF. Body usually stout and oval; beak three-jointed. VELIDAE

EE. Last segment of tarsus entire, and with claws inserted at apex.

F. Antennæ of three or four segments.

G. Beak three-jointed.

H. Body very long and slender . . EMESIDAE

HH. Body not long and slender.

I. Front legs with greatly thickened femora. Ambush-bugs. (Page 114) . PHYMATIDAE

II. Front legs with normal femora, or at least not unusually wide.

J. Antennæ of three segments. Assassin-bugs. (Page 112) . . . . . REDUVIIDAE

JJ. Antennæ of four segments.

K. Tarsus of two segments; body very flat. Flat-bugs . . . . . ARADIDAE

KK. Tarsus of three segments.

L. Dorsal portion of body more or less rounded; beak long, reaching to or beyond second coxa. Shore-bugs. SALDIDAE

LL. Dorsal part of body flat; beak not reaching beyond second coxa. Bed-bugs. (Page 114) ACANTHIDAE

GG. Beak four-jointed.

H. Ocelli absent.

I. Membrane of front wings with two large cells at the base, from which arise about eight branching veins. Red-bugs. PYRRHOCORIDAE

II. Membrane of front wings with one or two closed cells at the base, and with no longitudinal veins. Leaf-bugs. (Page 117) CAPSIDAE

HH. Ocelli present.

I. Front legs fitted for grasping prey, the tibia being armed with spines and capable of being closed tightly on the femora, which are unusually stout. Damsel-bugs . . . NABIDAE

II. Front legs not differing from the others.

J. Body and legs very long and slender. Stilt-bugs . . . . BERYTIDAE

JJ. Body not unusually slender.

K. Tarsus two-jointed; wing-covers resembling lace network. Lace-bugs. (Page 117) . . . . TINGITIDAE

KK. Tarsus three-jointed.

L. Membrane with four or five simple veins arising from its base. Chinch-bug family. (Page 120) LYGAEIDAE

LL. Membrane with many forked veins springing from a transverse basal vein. Squash-bugs. (Page 121) COREIDAE

FF. Antennæ of five segments.

G. Dorsal portion of body flat.

H. Tibia with few or no spines. Stink-bugs. (Page 115) . . . . PENTATOMIDAE

HH. Tibia armed with rows of spines . CYDNIDAE

GG. Dorsal portion of body strongly convex.

H. Prothorax rounded in front, nearly straight behind; lateral margin of scutellum with a furrow in which the edges of the wing-covers fit when closed. Negro-bugs . . . THYREOCORIDAE

HH. Prothorax not as above; lateral margin of scutellum without furrow. Shield-backed bugs. SCUTELLERIDAE

BB. Wings membranous or sometimes leathery throughout; beak arising from the hinder parts of the lower side of the head. Suborder HOMOPTERA

C. Beak evidently arising from head; tarsi three-jointed; antennæ minute, bristlelike.

D. With three ocelli; males with musical organs. Cicadas. (Page 122). . . . . CICADIDAE

DD. With two ocelli or none; males without musical organs.

E. Antennæ inserted on sides of cheek beneath the eyes. FULGORIDAE

EE. Antennæ inserted in front of and between the eyes.

F. Pronotum prolonged posteriorly over the abdomen or at least over the scutellum. Tree-hoppers. (Page 124) MEMBRACIDAE

FF. Pronotum not prolonged above abdomen.

G. Hind tibia armed with one or two stout teeth and with short, stout spines at tip. Spittle-insects. (Page 124) . . . . CERCOPIDAE

GG. Hind tibia with two rows of spines. Leaf-hoppers. (Page 125) . . . . JASSIDAE

CC. Beak apparently arising from between the front coxæ, or absent; tarsi one- or two-jointed.

D. Hind femora fitted for leaping; antennæ of nine or ten segments with two bristles on apex. Jumping plant-lice. (Page 127) . . . . PSYLLIDAE

DD. Hind femora normal; antennæ usually with less than ten segments.

E. Legs long and slender; wings transparent. Plant-lice. (Page 127) . . . . APHIDIDAE

EE. Legs short; wings usually opaque.

F. Tarsus consisting of two joints; body covered with a whitish powder, male and female each with four wings. ALEYRODIDAE

FF. Tarsus consisting of one joint; adult male with two wings; female wingless, with the body scale-like or gall-like in form. Scale insects. (Page 129) COCCIDAE

KEY TO THE FAMILIES OF COLEOPTERA

A. Head not prolonged into beak. (*Coleoptera genuina.*)

B. First and second tarsus consisting of five segments; third tarsus consisting of four segments . . . . Section HETEROMERA

C. Head without distinct neck; narrower than thorax and more or less inserted in it; body wall hard. Darkling-beetles. (Page 165) TENEBRIONIDAE

CC. Head with distinct neck and as wide as prothorax; body soft and elytra flexible. Blister-beetles . . . . MELOIDAE

BB. First, second, and third tarsi of same number of segments.

C. Tarsi consisting of five segments . . . Section PENTAMERA

D. Antennæ filiform, with distinct cylindrical segments. Tribe ADEPHAGA

E. Legs adapted for swimming, aquatic in habits.

F. Eyes divided laterally, making apparently four compound eyes. Whirligig-beetles. (Page 140) . . GYRINIDAE

FF. Eyes not divided. Predacious diving-beetles. DYTISCIDAE

EE. Legs adapted for running; terrestrial in habit.

F. Antennæ inserted on front of head above base of mandibles. Tiger beetles. (Page 137) . CICINDELIDAE

FF. Antennæ inserted on sides of head between base of mandibles and eyes. Predacious ground-beetles. (Page 138) . . . . CARABIDAE

DD. Antennæ not filiform.

E. Antennæ capitate or clavate . . . Tribe CLAVICORNIA

F. Aquatic, legs fitted for swimming. Water-scavenger beetles. (Page 141) . . . . . HYDROPHILIDAE

FF. Terrestrial, legs not fitted for swimming.

G. Antennæ moniliform, the segments gradually enlarging toward the end; elytra covering only basal half of abdomen. Rove-beetles . STAPHYLINIDAE

GG. Antennæ of various forms (clavate or capitate); elytra covering most of abdomen.

H. Abdomen with six or more ventral segments; anterior coxæ conical; antennæ gradually thickened or clavate. Carrion-beetles. (Page 142) SILPHIDAE

HH. Abdomen with five ventral segments; anterior coxæ conical and projecting from the coxal cavities; last three segments of the antennæ forming a large club. Larder-beetles, etc. DERMESTIDAE

EE. Antennæ serrate or lamellate.

F. Antennæ serrated. Saw-horned beetles. (Page 144) Tribe SERRICORNIA

G. Head inserted in thorax, which extends as far as compound eyes; body elongated or elliptical.

H. First two abdominal segments fused together on ventral side. Metallic wood-borers. (Page 146) BUPRESTIDAE

HH. First two abdominal segments not fused. Click-beetles. (Page 144) . . . . ELATERIDAE

GG. Head not inserted in thorax as far as compound eyes.

H. Head bent nearly at right angles to thorax, which protrudes over it. Size usually less than one fourth of an inch . . . . . . PTINIDAE

HH. Head normal, but partially or nearly covered by thin anterior margin of thorax.

I. Wing-covers flexible; body elongated and flattened; antennæ not enlarged at tip. Fire-flies. (Page 147) . . . . LAMPYRIDAE

II. Wing-covers firm; body not much flattened; antennæ often enlarged at tip. Checkered-beetles . . . . CLERIDAE

FF. Antennæ lamellate, composed of a stemlike portion on the end of which are a number of flat, bladelike segments . . . . Tribe LAMELLICORNIA

G. Antennæ elbowed; terminal lamella consisting of fixed transverse plates. Stag-beetles. (Page 148) LUCANIDAE

GG. Antennæ not elbowed; terminal lamella consisting of flat plates which fold together. Leaf chafers and scavenger-beetles. (Page 149) . SCARABAEIDAE

CC. Tarsus less than five segments.

D. Tarsus consisting of four segments. (Page 153) Section TETRAMERA

E. Body short and more or less oval; antennæ short.

F. Front of head not prolonged as a short, broad beak; elytra usually covering tip of abdomen; larvæ and adults leaf feeders. Leaf-beetles. (Page 153) CHRYSOMELIDAE

FF. Front of head prolonged as a short, quadrate beak; elytra short, exposing tip of abdomen. Pea- and bean-weevils. (Page 158) . . . . BRUCHIDAE

EE. Body long and cylindrical; antennæ long. (Page 158) CERAMBYCIDAE

DD. Tarsus consisting of three segments; comparatively small beetles with hemispherical bodies. Ladybird beetles. (Page 161) (Section TRIMERA) . . . . COCCINELLIDAE

AA. Head prolonged into a beaklike structure at the end of which are biting mouth-parts.

B. The dorsum of the last segment of the male divided transversely so that, when viewed dorsally, this sex appears to have one more body segment than the female.

C. Mandibles with a scar on the anterior aspect . OTIORHYNCHIDAE

CC. Mandibles without scar on anterior aspect. Curculios. (Page 167) CURCULIONIDAE

BB. Dorsum of last segment of both sexes undivided.

C. Tibia not serrated. Bill-bugs and granary-weevils. (Page 169) CALANDRIDAE

CC. Tibia serrated. Bark-beetles. (Page 170) . . . SCOLYTIDAE

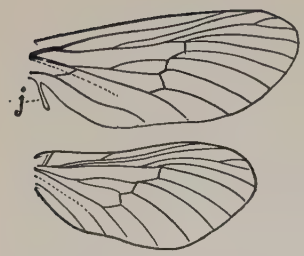

FIG. 437. Diagram of wings of *Hepialus gracilis*, showing jugum (*j*) and similarity of venation of fore- and hind-wings

(After Comstock, from Kellogg)

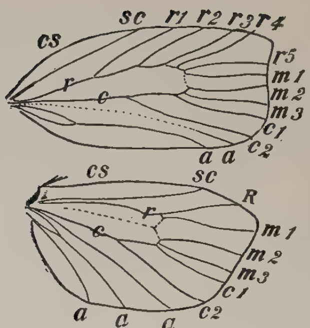

FIG. 438. Venation of a tortricid moth (*Cacoecia cerasivorana*)

(After Comstock, from Kellogg)

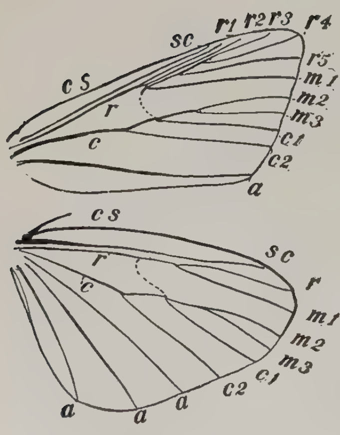

FIG. 439. Venation of a pyralid moth (*Pyralis farinalis*)

cs, costal vein; *sc*, subcostal vein; *r*, radial vein; *m*, medial vein; *c*, cubital vein; *a*, anal vein. Note the hairlike projection, the frænulum, at the base of the hind-wing. This fits into a little pocket on the fore-wing. (After Comstock, from Kellogg)

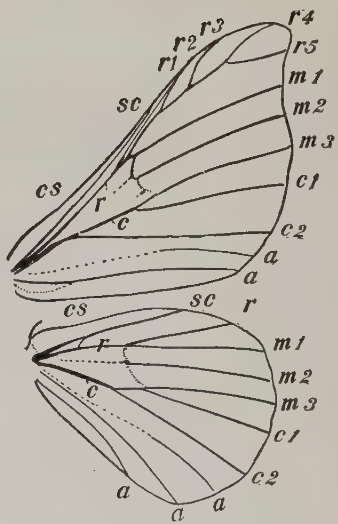

FIG. 440. Venation of a saturniid (*Bombyx mori*)

(After Comstock, from Kellogg)

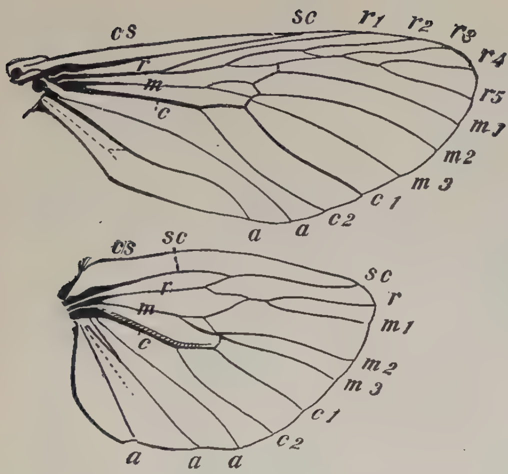

FIG. 441. Venation of a cossid (*Prionoxystus robiniae*)

(After Comstock, from Kellogg)

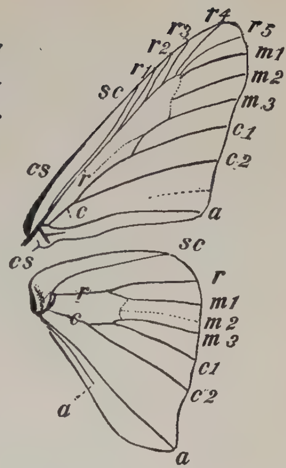

FIG. 442. Venation of a hesperid (*Epargyreus tityrus*)

(After Comstock, from Kellogg)

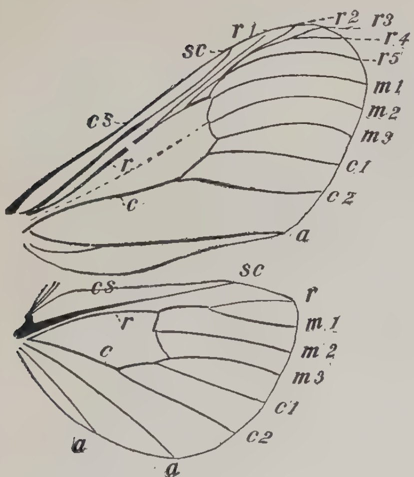

FIG. 443. Venation of a notodontid (*Notodonta stragula*)

(After Comstock, from Kellogg)

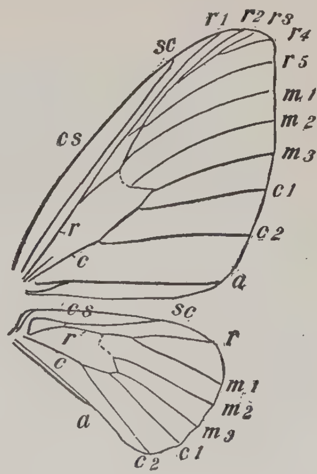

FIG. 444. Venation of a geometrid (*Dyspepteris abortivaria*)

(After Comstock, from Kellogg)

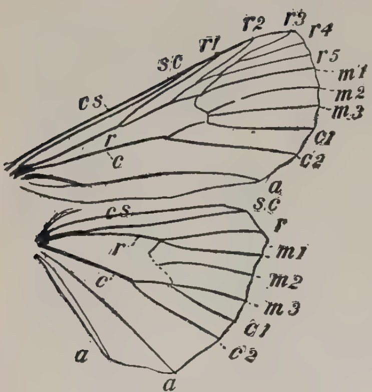

FIG. 445. Venation of a noctuid (*Agrotis ypsilon*)

(After Comstock, from Kellogg)

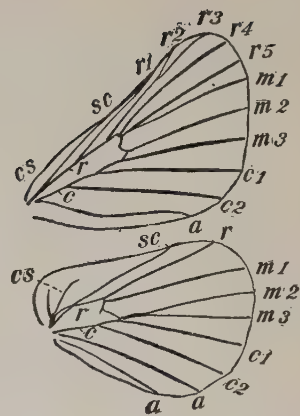

FIG. 446. Venation of a lasiocampid (*Malacasoma americana*)

(After Comstock, from Kellogg)

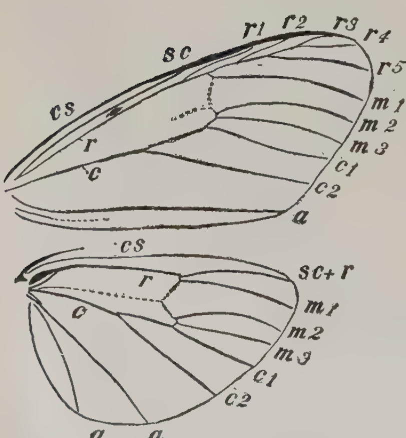

FIG. 447. Venation of a zygaenid (*Ctenucha virginica*)

(After Comstock, from Kellogg)

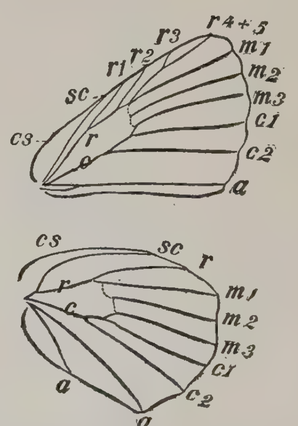

FIG. 448. Venation of a lycaenid (*Chrysophanus thoe*)

(After Comstock, from Kellogg)

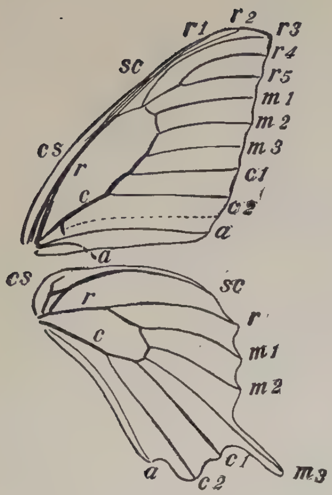

FIG. 449. Venation of a papilionid (*Papilio polyxenes*)

(After Comstock, from Kellogg)

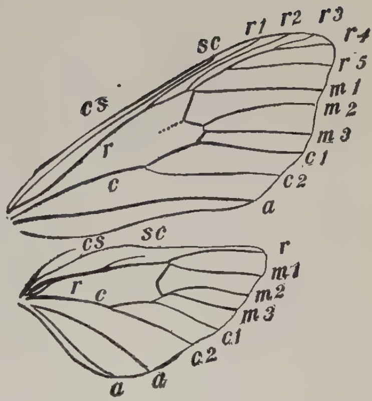

FIG. 450. Venation of an arctiid (*Halesidota tessellata*)

(After Comstock, from Kellogg)

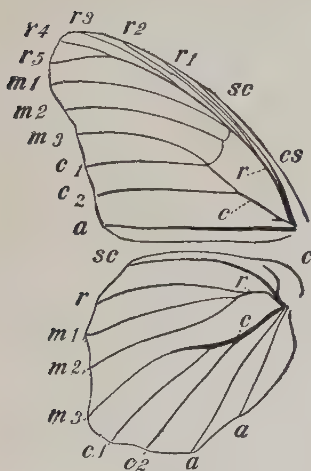

FIG. 451. Venation of a nymphalid (*Basilarchia astyanax*)

(After Comstock, from Kellogg)

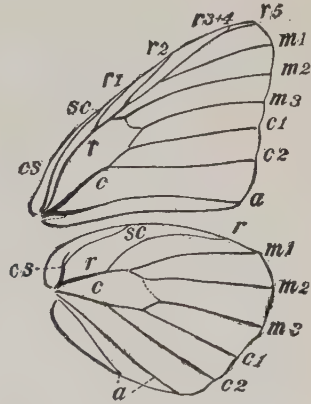

FIG. 452. Venation of a pierid (*Pontia protodice*). (Enlarged)

(After Comstock, from Kellogg)

KEY TO THE FAMILIES OF LEPIDOPTERA[1]

A. Lepidoptera with slender antennæ, the tips of which are expanded or dilated. Mostly diurnal in habits. Butterflies and skippers.

B. Dilation of antennæ terminated by recurved hook. Wing venation as in Fig. 261. Skippers. (Page 174) . . . . . . HESPERIDAE

BB. Dilation of antennæ not terminated by recurved hook.

C. First pair of legs normal, or simply reduced in size.

D. First pair of legs reduced in size. Wing venation as in Fig. 448. (Page 178) . . . . LYCAENIDAE

DD. First pair of legs normally developed.

E. Front tibia without pads; claws toothed; cubital of fore-wing three-branched. Fig. 452. (Page 178) . PIERIDAE

EE. Front tibia with pads; claws not toothed; cubital of fore-wing four-branched. Fig. 449. Swallowtails. (Page 175) PAPILIONIDAE

CC. First pair of legs atrophied, without claws; wing venation as in Fig. 451. (Page 179) . . . . NYMPHALIDAE

AA. Lepidoptera with antennæ of various forms but never enlarged at tip. Mostly nocturnal in habits. Moths.

B. Hind-wings with not over two complete anal veins.

C. Second and third median veins arising together; m^2 not arising from center of discal cell.

D. Humeral vein present in hind-wing, arising at base of costal. Frænulum absent. Fig. 446. (Page 216) . LASIOCAMPIDAE

DD. Humeral vein absent; frænulum present.

E. Subcosta and radius of hind-wing fused to near apex of discal cell; ocelli present. Tiger moths. Fig. 450. (Page 207) . . . . ARCTIIDAE

EE. Subcosta and radius of hind-wing distinct, or but slightly fused.

F. Diurnal moths with simple antennæ and contrasting coloration. Wood nymphs . . . . AGARISTIDAE

FF. Nocturnal moths with simple or pectinate antennæ and without contrasting coloration.

G. Ocelli absent; antennæ pectinate. Tussock-moth. (Page 203) . . . . LIPARIDAE

GG. Ocelli present; antennæ usually simple. Owlet moths. Fig. 445. (Page 199) . . . NOCTUIDAE

CC. Second and third median vein not arising together, arising from center of discal vein.

D. Frænulum present.

E. Subcosta and radius of hind-wing connected near base by crossbar. Hawk moths. (Page 208) . . . SPHINGIDAE

[1] This key has been adapted from keys of Holland, Smith, Bunter, and others.

EE. Subcosta and radius of hind-wing not connected by crossbar.

F. Moths with heavy abdomens and narrow, strong fore-wings. Prominents. Fig. 443. (Page 193) NOTODONTIDAE

FF. Moths with narrow, slender abdomens, and broad, delicate wings. Fig. 444. (Page 195) . GEOMETRIDAE

DD. Frænulum absent.

E. Tongue absent; tibia without spurs. Fig. 440. (Page 212) Superfamily SATURNOIDEA[1]

EE. Tongue present; tibia with spurs. Royal moths. CERATOCAMPIDAE

BB. Hind-wing with three complete anal veins.

C. Wings transparent, free from scales. Fore-wings narrow. Clear-winged moths. (Page 192) . . . . SESIIDAE

CC. Wings covered with scales.

D. Hind-wings with subcosta fused with or approximate to radius. Fig. 439. (Page 187) . . . . PYRALIDAE

DD. Hind-wings with subcosta and radius far apart.

E. Small moths with fringe on inner angle of hind-wing unusually long.

F. Second anal vein of hind-wing forked at base. Leaf-rollers. Fig. 438. (Page 186) . . . TORTRICIDAE[2]

FF. Second anal vein of hind-wing not forked at base. Leaf-miners. (Page 184) . . . . TINEIDAE

EE. Large or medium-sized moths, without unusual fringe on hind-wing.

F. Anal veins of fore-wing partially fused. Bag-worm moths . . . . PSYCHIDAE

FF. Anal veins of fore-wing not fused. Carpenter moths. (Page 191) . . . . COSSIDAE

KEY TO THE FAMILIES OF HYMENOPTERA[3]

A. Posterior trochanter consisting of two segments; ovipositor modified into a saw, or borer.

B. Abdomen broadly joined to thorax.

C. Tibia of forelegs with two terminal spurs; female with sawlike ovipositor. Saw-flies. (Page 244) . . . . TENTHREDINIDAE

CC. Tibia of foreleg with one terminal spur; female with ovipositor fitted for boring. Horn-tails. (Page 246) . . . . . SIRICIDAE

BB. Abdomen joined to thorax by slender petiole.

[1] Includes families Bombycidae, Saturniidae.

[2] Includes families Grapholithidae, Conchylidae, and Tortricidae.

[3] Modified from Cresson.

C. Fore-wings with few or no cross veins; if a few cross veins are present, the abdomen is not compressed. Very small parasitic Hymenoptera.

D. Ovipositor issuing before apex of abdomen . CHALCIDIDAE

DD. Ovipositor issuing from apex of abdomen. (Page 253) PROCTOTRYPIDAE

CC. Fore-wings with one or more closed cells.

D. Fore-wings without a stigma, or costal vein. Gall-flies. (Page 246) . . . . CYNIPIDAE

DD. Fore-wings with a stigma.

E. Fore-wing with two recurrent veins . ICHNEUMONIDAE

EE. Fore-wing with one recurrent vein . . BRACONIDAE

AA. Posterior trochanter consisting of a single segment.

B. Fore-wings with no closed submarginal cells.

C. Abdomen long and slender; antennæ long and filiform. PELECINIDAE

CC. Abdomen short, but little longer than the head and thorax together; antennæ short and elbowed. Cuckoo-flies . . . CHRYSIDIDAE

BB. Fore-wings with at least one closed submarginal cell.

C. First abdominal segment, and sometimes the second, forming a knot, or node, on the upper side of the petiole. Ants. (Page 254) Superfamily FORMICINA

D. First segment of the abdomen forming the petiole.

E. Abdomen somewhat constricted between the second and third segments; sting present . . . . . PONERIDAE

EE. Abdomen not constricted between the second and third segments; sting absent . . . . CAMPONOTIDAE

DD. Petiole consisting of the first and second segments of abdomen; sting present . . . . MYRMICIDAE

CC. Petiole normal, without scales or nodes.

D. First segment of tarsus of hind-leg cylindrical, and naked, or with little hair.

E. Wings folded longitudinally when at rest. True wasps. (Page 263) . . . . Superfamily VESPINA

F. Antennæ clavate or knobbed at tip . . MASARIDAE

FF. Antennæ filiform or nearly so.

G. Tibia of second pair of legs with a single terminal spur . . . . EUMENIDAE

GG. Tibia of second pair of legs with two terminal spurs. Tarsal claws simple. (Page 264) VESPIDAE

EE. Wings not folded longitudinally when at rest. Digger-wasps. (Page 260) . . . . . . Superfamily SPHECINA

F. Sides of the pronotum extending back to the base of the wings.

G. First abdominal segment distinctly separated from the second on the ventral side by a constriction.

H. Tibia of second pair of legs with two terminal spurs; females wingless. Velvet ants. (Page 261) . . . . MUTILLIDAE

HH. Tibia of second pair of legs with single terminal spur . . . . SCOLIIDAE

GG. First and second segment of abdomen not separated on ventral side by constriction. (Page 261) PSAMMOCHARIDAE

FF. Prothorax forming a narrow collar, not reaching to base of wing.

G. Base of abdomen with a long, slender petiole. (Page 262) . . . . SPHECIDAE

GG. Base of abdomen without long, slender petiole. BEMBECIDAE

DD. First segment of tarsus of hind-leg expanded and flattened, furnished with numerous hairs, often poorly developed in parasitic bees. Bees. (Page 266) . . . . Superfamily APINA

E. Glossa short and flat, no longer than the mentum. Short-tongued bees. (Page 267) . . . . . . ANDRENIDAE

EE. Glossa long and slender, not flattened. Long-tongued bees. (Page 267) . . . . APIDAE

KEY TO THE MORE IMPORTANT FAMILIES OF DIPTERA[1]

A. Adults nonparasitic upon the warm-blooded vertebrates; habits variable. Abdomen distinctly segmented. Rarely viviparous.

B. Anal cell rarely narrowed at the margin; antennæ consisting of more than 5 joints, usually elongate, filiform, and verticellate, rarely pectinate or with a differentiated style or arista . . . NEMATOCERA

C. Veins of the wings covered with hairs, the usual cross veins wanting. Small mothlike flies . . . . PSYCHODIDAE

CC. Veins and margin of the wings fringed with scales. Mosquitoes. (Fig. 455) . . . . CULICIDAE

D. Thorax with a distinct V-shaped suture; wings variable. Crane-flies. (Fig. 453) . . . . TIPULIDAE

DD. Thorax without the distinct V-shaped suture.

E. Discal cell present. False crane-flies . . . RHYPHIDAE

EE. Discal cell wanting.

F. Wings with few longitudinal veins; tibiæ without spurs. Gall-gnats. (Fig. 458) . . . . . . CECIDOMYIIDAE

FF. Tibiæ with spurs; coxæ elongate. Fungus-gnats. (Fig. 459) . . . . MYCETOPHILIDAE

[1] By C. W. Johnson, Curator Boston Society of Natural History.

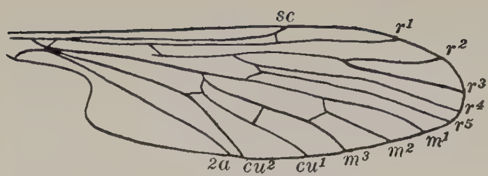

FIG. 453. Venation of a tipulid (*Protoplasa fitchii*)
(After Comstock)

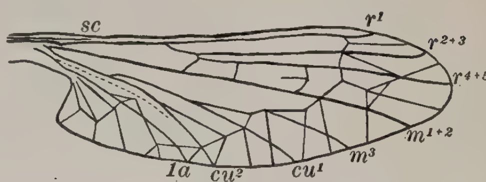

FIG. 454. Venation of *Blepharocera* sp.
(After Comstock)

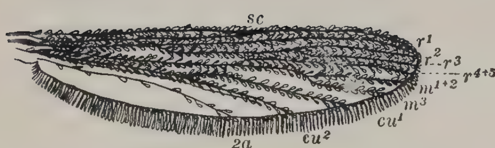

FIG. 455. Venation of a mosquito (*Culex* sp.)
(After Comstock)

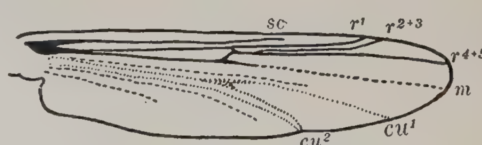

FIG. 456. Venation of a *Chironomus* sp.
(After Comstock)

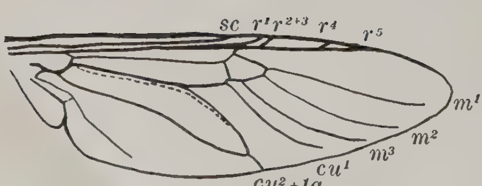

FIG. 457. Venation of a soldier-fly (*Stratiomyia* sp.)
(After Comstock)

G. Abdomen slender; wings narrow; antennæ plumose in the males. Midges. (Fig. 456) CHIRONOMIDAE

GG. Abdomen short and thick; antennæ shorter than the thorax, nonplumose.

H. Wings very broad, anterior veins stout, the other weak. The black-flies . . . . SIMULIIDAE

HH. Wings large but more normal in character; legs strong, front femora often thickened. BIBIONIDAE

BB. Anal closed or distinctly narrowed, second vein never furcate; antennæ usually with three joints, the third joint sometimes complex and composed of numerous annuli . . . . BRACHYCERA

C. Third joint of the antennæ with from 4- to 8-segmented annuli.

D. Squamæ rather large; third joint of the antennæ without a style or arista. Horse-flies . . . . TABANIDAE

DD. Squamæ small or vestigial.

E. Costal vein does not extend beyond the tip of the wing, longitudinal veins covered anteriorly; posterior veins often weak; tibiæ without spurs. Soldier-flies. (Fig. 457) STRATIOMYIDAE

EE. Costal vein encompasses the wing; posterior veins strong; middle tibiæ at least with distinct spurs; antennæ extremely variable . . . . LEPTIDAE

CC. Third joint of antennæ simple, not composed of numerous annuli.

D. Antennæ long, clavate, apparently 4-jointed; palpi small or wanting. Mydas-flies . . . . MYDAIDAE

DD. Antennæ 3-jointed, often with a variable style or arista; palpi always present, usually prominent. Robber-flies . ASILIDAE

E. Antennæ apparently 2-jointed; anterior veins stout, the others weak and extending obliquely across the wing. Small hunch-backed flies . . . . PHORIDAE

EE. Antennæ 2- or 3-jointed; head small; squamæ very large; abdomen inflated. Parasitic on spiders . . CYRTIDAE

F. Third antennal joint usually with a terminal style, proboscis often prominent; body frequently covered with long, delicate hairs. Bee-flies. (Fig. 460) BOMBYLIIDAE

FF. Third antennal joint without terminal style; fourth vein terminates at or before the tip of the wing. Window-flies . . . . SCENOPINIDAE

G. Small, for the most part bright-colored green or blue; second discal cell confluent with the discal cell; arista dorsal or terminal. Predacious. DOLICHOPODIDAE

GG. Small, not brightly colored; head small, eyes sometimes contiguous; proboscis rigid. Predacious. EMPIDIDAE

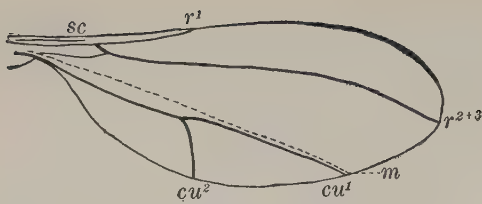

FIG. 458. Venation of a cecidomyiid gall-gnat
(After Comstock)

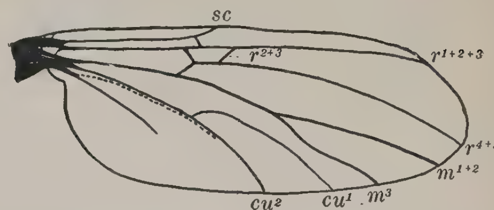

FIG. 459. Venation of a fungus-gnat (*Mycetophilidae*)
(After Winnertz, adapted from Comstock)

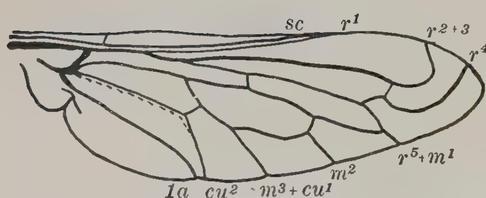

FIG. 460. Venation of a bombyliid (*Pentarbes capito*)
(After Comstock)

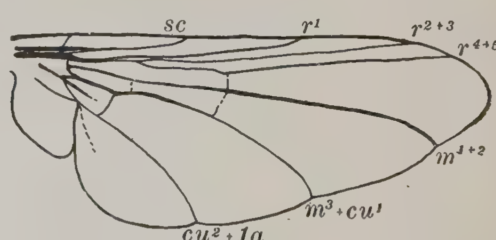

FIG. 461. Venation of a bot-fly (*Gastrophilus* sp.)
(After Comstock)

H. Third joint almost always with a dorsal arista; a spurious longitudinal vein between the third and fourth longitudinal veins; first posterior cell always closed. Flower-flies. (Fig. 463) SYRPHIDAE

HH. No spurious longitudinal veins.

I. Small; hind tarsi enlarged and often ornamented in the male arista terminal. Flat-footed flies . . . . . . PLATYPEZIDAE

II. Small; head large, composed chiefly of eyes; arista dorsal. Big-eyed flies. PIPUNCULIDAE

J. Squamæ small or vestigial; eyes never contiguous; the front in both sexes of equal width; thorax without complete transverse suture . . . . ACALYPTERAE

K. Auxiliary vein distinct, the first vein ends near or beyond the middle of the wings; a distinct bristle on each side of the face; oral vibrissæ present; front usually with well-developed bristles and hairs . . . . . . CORDYLURIDAE

KK. Front never bristly near the antennæ; abdomen cylindrical, contracted near the base. Small shining black flies. Cheese-maggot, etc. . . . SEPSIDAE

L. No oral vibrissæ; abdomen elongate, often narrowly constricted, proboscis long and folded near the middle. (Fig. 462) . CONOPIDAE

LL. Upper fronto-orbital bristles only present; preapical tibial bristle rarely present; arista rarely plumose; ovipositor horny; wings usually pictured . . . . . . ORTALIDAE

M. Fronto-orbital bristles present or absent; second joint of the antennæ often elongate; arista plumose; preapical tibial bristle present; ovipositor not horny; wings often pictured. Meadow-flies . . . SCIOMYZIDAE

MM. One or two fronto-orbital bristles; third joint of the antennæ more or less elongate; preapical bristle absent or present. All small species. SAPROMYZIDAE

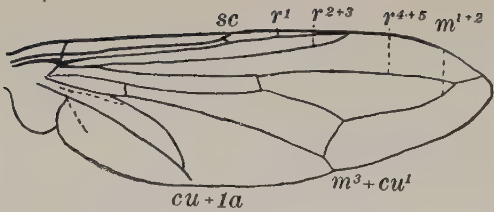

FIG. 462. Venation of a conopid (*Conops affinis*)
(After Comstock)

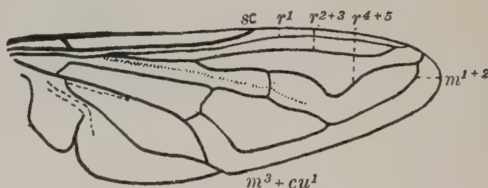

FIG. 463. Venation of a syrphid (*Eristalis* sp.)
(After Comstock)

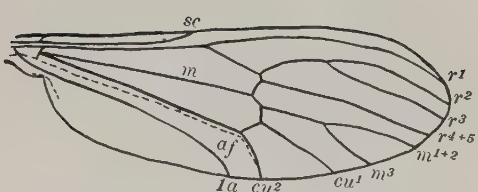

FIG. 464. Venation of a dixa midge (*Dixa* sp.)
(After Comstock)

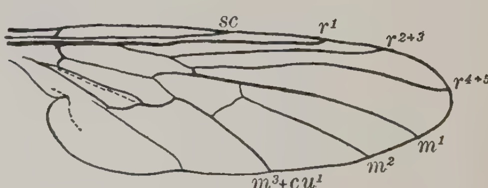

FIG. 465. Venation of an empidid (*Rhamphomyia* sp.)
(After Comstock)

N. Auxiliary vein absent or incomplete; first vein usually ends in the costa before the middle of the wing; head produced on each side into a lateral process for the eyes . . . DIOPSIDAE

NN. Hind metatarsi incrassated and usually shorter than the second joint; oral vibrissæ present. Small flies about excrement near water. BORBORIDAE

O. Discal and basal cells united, anal cell absent; front bare or at most bristly above. Small, usually light-colored flies . . OSCINIDAE

OO. Front often bristly, face often very convex, mouth cavity usually large; no oral vibrissæ. Small dark-colored flies about water. EPHYDRIDAE

P. Anal cell complete; oral vibrissæ present; aristæ long, plumose, or pectinate above. Vinegar or pomace flies. DROSPHILIDAE

PP. Arista bare or pubescent; front bristly at least as far as the middle. Very small flies, comprising most of the leaf-miners. AGROMYZIDAE

Q. Oral vibrissæ absent; anal cell angular; no preapical tibial bristle;

ovipositor long and jointed; wings usually pictured. Fruit-flies.
TRYPETIDAE

QQ. Anal cell not produced; antennæ usually elongated and decumbent. Rather small elongate flies.
PSILIDAE

JJ. Squamæ large; front of male narrowed or eyes contiguous; thorax with complete transverse suture . . . CALYPTERAE

K. Oral opening small; the mouth-parts small or vestigial. Larvæ parasitic upon mammals. Bot-flies. (Fig. 461)
OESTRIDAE

KK. Oral opening of usual size, not vestigial; hypopleuræ with a tuft of bristles; first posterior cell narrowed or closed; arista bare or somewhat pubescent. Larva parasitic upon the early stages of other insects . . . . . . TACHINIDAE

L. Arista bare on the outer half; dorsum of the abdomen rarely bristly on the anterior part. Larva usually feeds on decaying animal matter. Flesh-flies . . SARCOPHAGIDAE

LL. Arista entirely plumose; dorsum of the abdomen usually bristly on the anterior part; legs long. Larva parasitic on other insects . DEXIIDAE

M. Arista plumose; abdominal segments without bristles except near the tip; first posterior cell narrowed or closed. House-fly, etc. . . . . MUSCIDAE

MM. Arista plumose, pubescent, or bare; first posterior cell very slightly or not at all narrowed at the margin. Larva are vegetable feeders. ANTHOMYIIDAE

AA. Adults usually ectoparasitic upon warm-blooded vertebrates; abdomen indistinctly segmented. Larvæ born when about to pupate. PUPIPARA

B. Winged or wingless flies; eyes faceted; palpi forming a sheath for the proboscis; veins of the wing, when present, crowded anteriorly, the weaker veins running obliquely across the wing. Parasitic upon birds and mammals. Louse-flies . . . . HIPPOBOSCIDAE

BB. Winged or wingless; when present the wings are pubescent, with parallel veins and outer cross-veins; eyes usually unfaceted; ocelli wanting; antennæ 2-jointed; palpi broad, not forming a sheath for the proboscis. Usually parasitic upon bats . . . . STREBLIDAE

C. Wingless; halteres present; eyes vestigial; head folding back on the dorsum of the thorax. Small, spiderlike flies; parasitic upon bats. Bat-ticks . . . . NYCTERIBIIDAE

CC. Wingless; halteres absent; eyes vestigial; last joint of the tarsi with a pair of comblike appendages. Parasitic upon the honey-bee. Bee-louse . . . . BRAULIDAE

CHAPTER XXIII

METHODS OF COLLECTING INSECTS

The following instructions on the methods and equipment for collecting and preserving insects have been compiled to give as concise information on the subject as possible. Most of the methods and equipment have been tried and tested out either by the author or under his observation. There are a number of accessible bulletins and papers on this subject, one of the best of which is *United States National Museum Bulletin No. 67*, "Directions for Collecting and Preserving Insects," by Nathan Banks.[1]

Field kit. In order to secure a collection that is at all valuable, it is necessary to make special trips after insects, and to be provided with special equipment. Therefore, among the first requirements is a means of carrying the outfit so that every article will be accessible.

The haversack. This is one of the most common means of carrying collecting outfits, and if constructed of the proper material, will be found very handy. The size will depend somewhat on the length of the trip taken, but for ordinary purposes a sack twelve by fourteen by four inches will be found most convenient. It should be provided with a good flap, to fasten by means of a buckle or snap, as well as with shoulder straps and loops for the belt. These latter are very important, as they prevent the sack from flopping about while collecting. Canvas or khaki makes very serviceable sacks, but they are not waterproof. Some of the numerous imitation leathers or heavy oilcloth will wear nearly as long and be much more serviceable. The haversack should have at least three separate compartments, and if manufactured at home, with a little ingenuity one can provide a place for each article of the outfit.

Collecting coat. Any comfortable, loose-fitting coat may, with a little alteration, be converted into an entomologist's collecting coat. The requirements are a sufficient number of pockets to hold the

[1] See also the bottom of page 359.

field outfit. The ordinary khaki or duck's-back hunting coat will be found very convenient, having, as it does, an abundance of room for accommodating cyanide bottles, folding nets, and other necessary articles.

Collecting belt (Fig. 466). For short, half-day excursions a loose-fitted, woven belt, about three or four inches wide, provided with pockets to hold cyanide bottles, forceps, storage boxes, etc., is very

FIG. 466. A collecting belt
(After Banks)

serviceable. The objection to this affair, however, is the unavoidable width of the belt. These belts may be obtained, with a complete collecting outfit, from any of the entomological supply companies.

Insect nets. Of first importance to the entomologist is the insect net. In its simplest form the net consists of a ring, or hoop, firmly attached to a handle two or three feet in length. Attached to the hoop is a net about eighteen inches in depth. A very serviceable net may be constructed by bending a stout wire into a circle (Fig. 467), then bending the ends back at right angles and lashing them

firmly to the stick with stout binding wire. The ring will be held much more firmly if the ends of the wire are sharpened and again bent at right angles and driven into the stick. Also, a groove cut in either side of the stick for the reception of the wire will make it much stouter. There are numerous other ways of constructing net frames, but most of them are too complicated for practical use. Many folding frames of various types may be obtained of entomological supply companies, but none of these are equal to the spring-steel, folding landing nets sold by dealers in fish tackle. These may be obtained with a three-foot, jointed handle, are nearly as light, and will stand much more wear than any of the regular insect-net frames on the market. The simplest and lightest net ring is that of the simplex net (see Appendix); this consists of a thin steel band which is easily coiled up and carried in the pocket, and readily attached to the handle. Numerous materials are used in the construction of the net itself. Mosquito bar is sometimes used, but this lasts but a short time and is too coarse to catch small insects. A fine bobbinet is far superior to the mosquito bar, as is also cheesecloth. With any of these materials a hem of stout cotton cloth should first be sewed to the net, through which to run the net frame. The net should be about eighteen inches in depth, tapering nearly to a point.

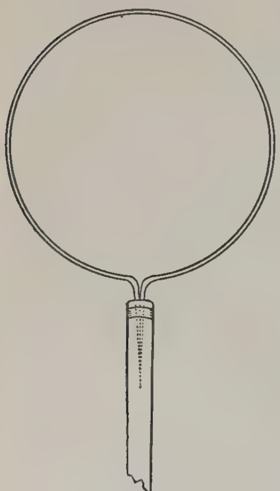

FIG. 467. A wire net frame

The net above described is to be used for all ordinary purposes, such as catching butterflies, dragon flies, etc., but is scarcely suitable for certain kinds of collecting.

The sweeping net. This type of net is very similar to the one just described, except that the frame is much heavier and the net of stronger material, such as denim or canvas. It is used by sweeping it back and forth rapidly over the tops of the bushes, through long grass, weed patches, etc. After sweeping back and forth a number of times, the net is given a half turn, which prevents the

insects from escaping. An improved form of this net consists of an outer sack with square in place of tapering bottom, the sack to be made out of cheesecloth, cotton cloth, or some such material. On the inside of this is fitted a short, funnel-shaped net made out of bobbinet or light cheesecloth. This net has an opening of about two inches at the bottom. In sweeping, the insects pass down through this opening between the two nets and are unable to escape. In this way great numbers of grass insects may be collected without stopping to remove them from the net. The insects may be stupefied by placing the entire net in a pail together with a piece of cotton saturated with ether.

For aquatic collecting certain other types of nets are desirable, although the ordinary insect net may sometimes be used to advantage.

Water dip net (Fig. 468). The frame of this type of net is usually flattened on one side so as to allow the net to be manipulated

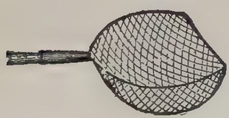

FIG. 468. A water dip net
(After Packard)

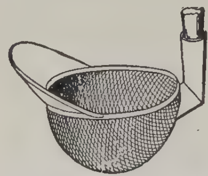

FIG. 469. A small dip net
(After Howard)

closer to the bottom. The net itself should be made of fine brass-wire netting, about twelve inches in diameter and of about the same depth. Fig. 469 shows a dip net with a flange, or lip, of tin or sheet iron, which is useful in dislodging aquatic larvæ or insects from around stones, thick weeds, etc.

The sag net (Fig. 470). This form of aquatic net is described by Professor James G. Needham, who is probably our best authority on aquatic insects, as follows:

It consists of a ring of stout spring wire three to four feet in diameter, to which is attached a very shallow bag of bobbinet, and at one side is a handle only long enough to be held readily. It is intended to catch insects adrift in the stream, and is accompanied by an instrument for dislodging them. Such an instrument is figured below the net. It consists of a handle three or

four feet long, with a double hook at one side and a brush at the other side at its distal end. To illustrate the use of this apparatus, suppose we wish to collect the insects from the stones obstructing a brook. We place the net directly below the obstruction and in the current, and adjust it to the bottom by downward pressure on the handle with one hand, while with the other we rapidly overturn the stone and with a brush sweep free the clinging insects. These are driven by the current into the net, when it is then lifted and emptied.

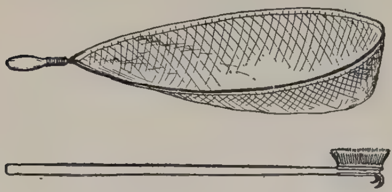

FIG. 470. Sag net, hook and brush for collecting in rapids

(After Needham)

An aquatic sieve net (Fig. 471). This net is intended to be used in stagnant water or on sandy bottoms where there is but little vegetation. The frame consists of a light steel rod, sides of heavy tin or galvanized iron, and a bottom of fine brass or galvanized wire netting. When provided with a long handle, this net may be used from the shore, and is particularly recommended for burrowing nymphs of aquatic insects.

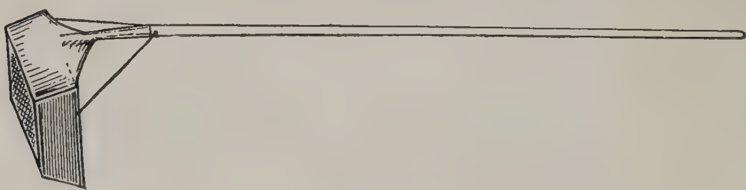

FIG. 471. An aquatic sieve net

(After Needham)

Rake net. The rake net consists of an ordinary garden rake, with a stiff semicircle of wire fastened on the upper side of the rake above the teeth. This should be braced to the handle with another piece of wire. A net is then attached to the upper part of the rake and around the semicircle of wire. This is very useful in slightly weedy water, or where there is a large amount of débris on the bottom. When the bottom of a pond or stream is raked, the insects, nymphs, and small crustaceans are either entangled in the débris and brought to shore, or, in trying to escape the rake teeth, swim back into the net. The débris should be carefully

searched for any nymphs or larvæ that may be entangled in it. This form of net is particularly useful in collecting dragon-fly nymphs, and is much superior to the ordinary garden rake, which has often been recommended for this purpose.

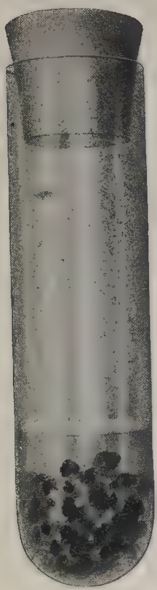

FIG. 472. A cyanide bottle for the pocket. (One half actual size)

Cyanide bottle (Figs. 472 and 473). These bottles should be provided in at least three sizes, the largest with a diameter of two and one half inches or more, a smaller, straight-necked bottle with a diameter of an inch and a half, and another much smaller straight-necked bottle with a diameter of about half an inch. Before much collecting is done, the student will probably find it necessary to provide himself with two complete sets of these bottles, with possibly one or two extra of the smaller sizes. Cyanide bottles are made in the following manner: Place a few good-sized pieces of potassium cyanide (a most deadly poison) in the bottom of each bottle, and cover the cyanide with dry plaster of Paris. (As the fumes of potassium cyanide are very poisonous, it should be handled with extreme care.) Then mix up a thick paste of plaster of Paris and water, and pour over the dry plaster in the bottles. Leave standing open for a few hours, until the water has evaporated

FIG. 473. A larger cyanide bottle with paper strips to give support to the insects

(After Banks)

and the plaster of Paris set. After this the bottle should always be kept corked, so as to retain the strength of the cyanide. The advantage in putting the dry plaster of Paris in first is that it absorbs the moisture and will keep the bottle dry longer than if the wet plaster is poured directly over the cyanide. It will also be found advantageous to place a few strips of dry blotting paper in each cyanide bottle, as this serves the double purpose of helping to absorb the moisture and preventing the insects from shaking about.

FIG. 474. Chloroform bottle with a brush stopper

(After Banks)

After the insects are caught in the net, they should be transferred to the cyanide bottle, which, if properly constructed, will stupefy them in a few seconds. Insects, especially beetles, should not be removed from the bottle for an hour, although Hymenoptera and Diptera will be killed within ten minutes. If the cyanide is too dry, it does not act so rapidly, and a few drops of soda water will greatly increase its efficiency. Very small cyanide bottles may be made by placing a piece of cyanide in the bottom, covered with cotton or blotting paper.

If possible, only insects of the same size should be placed together in the cyanide bottles. Fragile insects, or those with scaly wings, should not be put in with the general collection.

Chloroform bottle (Fig. 474). While not an absolute essential to the collecting of insects, the chloroform bottle will be found one of the most valuable assets, especially to the collector of Lepidoptera. One of the most convenient forms consists of a small-mouthed bottle, into the cork of which has been inserted a camel's-hair brush. These will be found most useful in collecting very small insects or butterflies. In collecting very small insects, touching them with a brush moistened in chloroform is sufficient to kill them, and at the same time the insects will adhere to the brush and may thus be transferred to the storage bottle or box. In collecting Lepidoptera the sides of the thorax should be moistened with the chloroform before placing them in the cyanide bottle.

Another form of chloroform bottle suitable for stupefying large Lepidoptera is made by inserting a fine-pointed medicine dropper through the cork of the bottle. A few drops of chloroform can then be applied directly to the specimens, through the net, before they are removed. This will also be found convenient in collecting some of the larger Hymenoptera. Since the chloroform has a tendency to harden the specimens, only a sufficient amount should be used to stupefy the insects, which should immediately be placed in the cyanide bottle.

Alcohol. This is another accessory that should be used in the field only in collecting very small insects, such as Thysanura, very small larvæ, Aphididae, etc. The alcohol outfit should consist of a number of small, straight-necked vials, fitted with cork stoppers, about half filled with 75 per cent alcohol. In addition to these vials the collector should have a larger bottle and brush, similar to the chloroform bottle described above. This bottle should contain 95 per cent of alcohol and 5 per cent of glycerin. The specimens are killed by touching them with the brush moistened in the 95 per cent alcohol, after which they are washed off into the bottle containing the weaker alcohol. The reason of this combination of two grades of alcohol is that many insects are protected with a waxy secretion which the weaker alcohol will not penetrate. Of course, specimens should not be collected in this way unless they are to be preserved permanently in some liquid medium. In collecting some Thysanura it may be found necessary to dispense with the glycerin, although it has a tendency to retain the color better than the alcohol alone.

Collecting forceps. While these are not absolutely essential to the field kit, it will be found convenient to have a pair of stout, broad-pointed forceps for handling stinging Hymenoptera, some beetles, and other insects that are liable to injure the collector. Fine-pointed forceps should also be taken along to handle very small insects, although a moistened camel's-hair brush will serve the same purpose.

Hatchet and chisel. These tools will be found very useful in collecting wood-boring insects and their larvæ. The marble safety ax stands in a class by itself, being far superior to anything else on the market for this purpose. Even in general collecting this ax will

be found very useful for numerous purposes. In addition to the ax, many collectors always carry a chisel, but this will be found of but little advantage except in collecting wood-boring larvæ.

Receptacles for carrying insects. For general collecting, one should always carry a number of receptacles in which to place the insects as soon as they have been killed in the cyanide bottle. For

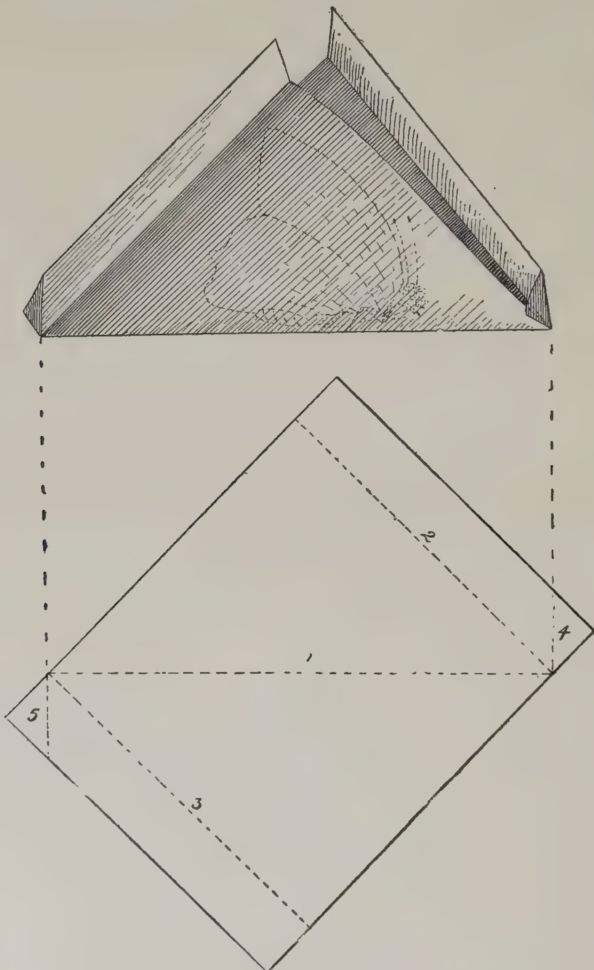

FIG. 475. The paper envelope for Lepidoptera, and method of folding it
1, first fold; *2*, second fold. (After Banks)

this purpose ordinary pill boxes of various sizes are most convenient. Each box should be partly filled with crushed tissue paper, to prevent the insects from shaking about. Care should be taken not to place too many insects together. If the insects cannot be mounted at once, the date of collecting, the locality, and other notes may be written on the outside of the box. For very small insects gelatin capsules will prove more useful than the pill boxes. Large-sized capsules especially adapted to this purpose may be obtained of entomological supply companies or large drug houses. Glass bottles should never be used for this purpose, as the moisture from the bodies of the insects soon causes them to deteriorate, or otherwise injures the more delicate specimens. Also, cotton should not be used in the pill boxes or capsules, as the claws and delicate hairs of the insects become entangled and often broken off. Small paper envelopes will be found very useful in carrying Lepidoptera, but they should be packed in a tin or wooden box to prevent crushing.

Collecting larvæ. The method of collecting larvæ depends somewhat upon the manner in which they are to be preserved. Small larvæ, to be preserved in alcohol or mounted on slides, may be placed directly in the alcohol-glycerin solution, as indicated above. The larger forms, which are to be blown (see page 353), should be placed in tin boxes, together with a small amount of their food plant. Aquatic forms which it is desirous to keep alive must be packed in damp moss or damp paper, or else carried in a large, open receptacle filled with water. If placed in a bottle or tightly closed receptacle, they will soon die. One danger of carrying aquatic larvæ or nymphs in water is that the larger forms will often destroy the smaller ones, especially if dragon-fly nymphs have been collected. There is much less liability of this occurring if the nymphs are packed in wet moss or paper.

Insect traps. Many insects can be collected much more easily by means of traps than in any other way. These traps may consist of some form of light for attracting insects, some attractive food from which the insects may be collected as they come to it, or a trap that the insects will fall into.

The funnel trap. The ordinary glass or tin funnel is frequently employed in trapping insects. One of the simplest ways

of using this is to fit a cyanide or alcohol bottle over the lower end of the funnel, and sink the bottle and funnel in the ground level with the surface. This is particularly useful along the coast or in sandy localities where ground beetles are numerous. This will prove more effective for carrion beetles if a dead fish, mouse, or piece of meat is strung on a wire and laid across the funnel. The funnel is also used in collecting very small insects, like Thysanura. The simplest method is to take an ordinary glass funnel, from twelve to twenty-four inches in diameter, and place a cork stopper in the lower end of the neck. The neck is to be partly filled with alcohol. The funnel should then be placed in a basin with straight sides, which is partly filled with water. The basin may be of tin or granite ware, of slightly smaller diameter than the top of the funnel, but deep enough so that the neck of the funnel does not rest on the bottom. If the funnel is not heavy enough to prevent floating, it may be held in position by strips of lead laid across the top. This apparatus should then be placed over a gas flame or some other even heat, and the temperature of the water raised to between sixty and one hundred degrees. Since alcohol evaporates so rapidly, it should not be placed in the funnel until the apparatus is ready for use. The material containing the insects, such as leaves, decayed wood, etc., is next placed in a sieve, the diameter of which is slightly smaller than that of the funnel. The sieve is then placed over the top of the funnel, and the insects, attracted by the heat, rapidly work their way through the material and drop down into the funnel. The insects are removed from the funnel by taking out the cork stopper and allowing the alcohol to run out into a bottle. A very convenient time to collect these small insects is during the early fall or winter. Cotton-cloth bags may be used to gather up the decaying leaves, wood, etc., which are then brought to the laboratory and the insects sorted out.

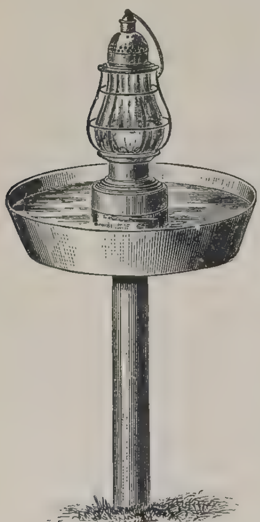

FIG. 476. A simple trap lantern

Many insects can be secured in the fall by providing suitable places in which they may hibernate, such as boards, old gunny sacks, etc. placed on the ground. Another method is to place strips of cloth or gunny sacks around the trunks of trees, and examine them frequently for insects.

Light traps. Numerous forms of traps have been constructed, to take advantage of the habit of some insects of flying toward the light. One of the simplest of these traps (Fig. 476) is made by placing an ordinary lantern in a shallow pan eighteen or twenty inches in diameter and four inches deep. This apparatus is then placed on a stump, fence post, or other conspicuous locality. The lantern is then lighted, and an inch or two of water, covered with a film of kerosene, is placed in the pan. Leave the trap overnight (the darker the better) and in the morning remove the insects and place them in gasoline or benzine for a short time, to remove the kerosene. They can then be laid on blotting paper, dried, and mounted in the usual way.

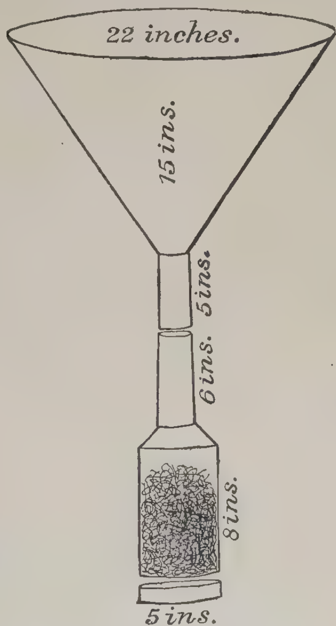

FIG. 477. The Gillette trap light

A lantern is hung over the mouth of the funnel

Another method of using the trap lantern is to suspend a lantern above a large tin funnel with a diameter of twenty or twenty-four inches. At the bottom of the funnel is placed a cyanide bottle. The insects, particularly beetles, fly against the light and fall into the funnel and, the sides being smooth, roll down into the cyanide bottle. Other more elaborate arrangements may be fitted up, but either of the above forms will do for most cases.

Baiting insects. This form of collecting is used principally in capturing moths and other insects that have a fondness for sweets. As usually practiced, the entomologist goes out just at

twilight with a mixture of sugar and rum, sugar and vinegar, or some such substance, which is painted on the trunks of trees. After an hour or so the trees are visited by the entomologist, who is armed with a dark lantern or a bicycle lantern. The moths are caught either by means of a net or by carefully approaching the tree and placing a large-mouthed cyanide bottle over the insects as they feed. Warm, cloudy nights are best for this work, although one is not always assured of success.

If pieces of decaying fish, meat, or other animal matter are placed in a convenient locality and examined from time to time, large numbers of beetles may be collected.

CHAPTER XXIV

METHODS OF PRESERVING AND STUDYING INSECTS

The work of the entomologist is only just begun when the insects are collected. They must then be pinned, dried, and labeled, the latter including the identification, which in itself is no little matter.

Mounting insects. Insects should be mounted as soon as possible after being killed. When it is impossible to mount them immediately, put the insects in shallow pill boxes packed in tissue paper, and set in a warm place to dry. When ready to mount, remove the lid and place the box in a tight glass jar, together with a sponge dipped in camphor water. The insects should be left in this chamber for from 24 to 48 hours, when they can be mounted as usual.

Insects should be mounted on insect pins. These are made especially for the purpose, are about an inch and a half in length, and range in size from No. 000, the most slender, up to No. 8, which is the largest. Nos. 1, 2, and 3, however, will do for nearly

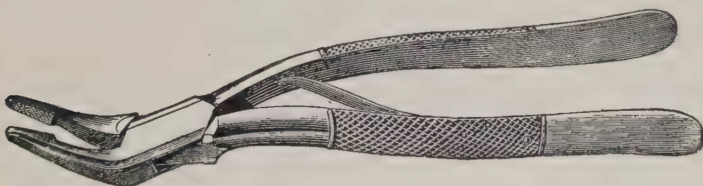

FIG. 478. Pinning forceps

all purposes, with a few of No. 5 for the larger moths. No. 3 is large enough for almost all larger insects, and insects too small for No. 1 should be mounted on points. The pins may be obtained in either the black japanned or the plain white metal; the latter, however, should be used only in mounting insects on points, as a green verdigris is produced near the insect, which corrodes the pin.

The collector should be careful to have all the insects at the same distance from the head of the pin; this not only makes the

collection look better, but also makes it much easier to handle and study. The general rule followed by entomologists is that one fourth of the pin shall project above the insect. For this purpose a pinning block is almost indispensable, the construction of which will be readily understood by referring to Fig. 479. The lower hole should be one fourth the length of the pin in depth, the second, one half the length, and the third, three fourths the length. After the pin has been pushed through the insect, the head is inserted in the lower hole and the insect pushed down until the back touches the block. The second hole is for evening up the labels, and the third one for placing points on the pins.

A great deal of skill is required in pinning insects properly. The specimen should be grasped by the thumb and forefinger

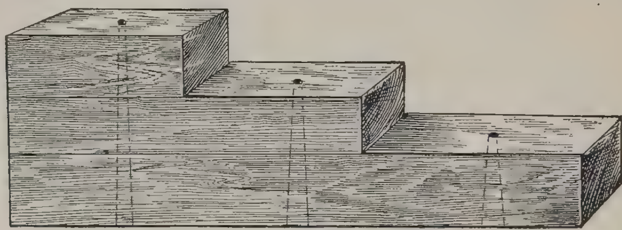

FIG. 479. A pinning block

and held very lightly in the groove formed between the tips of the thumb and forefinger while the pin is inserted in the proper place. Another method is to place the insects on some soft substance, as a folded handkerchief, and turning the insect ventral side down, insert the pin, finishing the operation on the pinning block.

Since the different groups of insects present certain structural peculiarities, the following system of pinning the members of different orders has gradually been formed. (The directions for mounting on points and slides are given below.)

Thysanura and Collembola. All of the smaller species are mounted on microscope slides ; the larger forms are pinned through the metathorax. A very fine wire is run entirely through the body, to serve as a support. In the case of the Thysanura, this should be inserted just underneath the long, median setæ and run forward well into the thorax. If the end is left projecting, it may be made to serve as a support for the posterior setæ.

May-flies, dragon-flies, and stone-flies. The pin is inserted in the metathorax, and a fine wire run from the end of the body into the thorax. In the case of the May-flies this wire should be left projecting to serve as a support for the posterior setæ, which should be attached to the wire. The wings of both the May-flies and dragon-flies should be spread. This is done by means of a spreading board.

Spreading boards. Fig. 480 shows the construction of a simple spreading board. Two soft-pine boards are placed parallel on short crosspieces, the boards being at a slight angle to each other. The edges of the board should be from one sixteenth to one half an inch apart, depending on the size of the insects to be mounted. A thin sheet of cork is glued to the underside of the boards. When the spreading board is used, the insect is pinned in the ordinary manner and the pin is then forced through the sheet of cork until the dorsal portion of the insect is nearly level with the upper surface of the boards. The spreading board, of course, must be selected with a groove wide enough to accommodate the body of the insect. After being placed on the spreading board, the wings of the insect are brought forward and held in position by narrow strips of paper or tracing cloth, as shown in the illustration. Glass-headed pins are handy for pinning the strips. The spreading board is then set away until the insect is thoroughly dry.

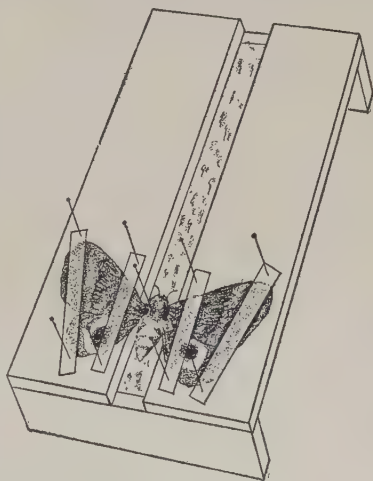

FIG. 480. Board showing method of spreading Lepidoptera. (Reduced)

In the case of the May-flies the front margins of the first pair of wings are brought forward until they are at right angles with the body. In the case of the dragon-flies the hind margins of the first pair of wings should be at right angles to the body. In pinning stone-flies, usually only the wings of the right side are spread,

although some entomologists spread the wings on both sides. The front margins of the hind pair of wings should be at right angles to the body, the front pair being brought forward until they just touch the hind pair.

Platyptera. White ants are usually mounted in alcohol, or on microscope slides, although the winged forms may be pinned through the metathorax. The wings are seldom spread. Book-lice are mounted either on points or on microscope slides, while bird-lice are invariably mounted on microscope slides. Earwigs are mounted on points, or, in the larger forms, the pin is inserted through the anterior portion of the right wing-cover.

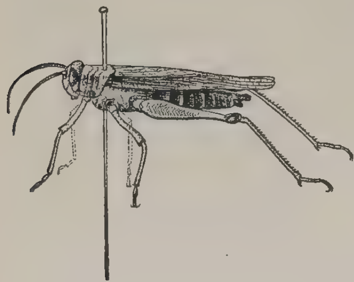

FIG. 481. Showing method of pinning Orthoptera

(After Washburn)

Orthoptera (Fig. 481). In the ordinary grasshopper, and in those forms having the pronotum well developed, the pin is usually inserted through the posterior margin of the pronotum. In forms in which the pronotum is not well developed the pin is run through the metathorax. The wings may or may not be spread, but the usual method is to spread the wings on the right side of the body. Care should be taken to arrange the legs and antennæ, the latter being laid back over the body, if possible. The legs may be held in position by running the pin through a square of stiff paper, which is brought up to the proper distance and the legs kept in a natural position until dry.

FIG. 482. Showing method of pinning Hemiptera

(After Washburn)

Hemiptera (Fig. 482). All of the larger Hemiptera are pinned through the metathorax; the smaller forms, with the exception of the Aphididæ and scale insects, are mounted on points. The two latter groups require special methods of mounting.

The Aphididæ are frequently mounted by placing them on a glass slide and covering them with a drop of Canada balsam dissolved in xylol. They are allowed to stand for twenty-four hours, when a small amount of fresh balsam is applied, and

the specimens covered with a cover glass. This method is far from satisfactory, as the balsam soon clouds, but at present it is the only thing that can be recommended as a permanent mount.

Two methods are employed in mounting scale insects. The entire scales are mounted by taking a thin strip of bark on which is found a colony of scales, and after leaving it in the cyanide bottle for twenty-four hours, it is placed between two pieces of celluloid. The two plates of celluloid are held apart by a cell cut out of cardboard, and the entire mount sealed with passe-partout tape. The thickness of the cell depends upon the thickness of the piece of bark to be mounted. It will be found very convenient to have these cells cut the size of an ordinary microscope slide. This form of mounting will do only for very superficial study, and some of the scales must be cleared and mounted in balsam. This is done by removing the scales from the bark and, in the case of the armored or flat scales, removing the insects from under the scales and placing them in a small test tube with caustic potash solution. These should be boiled until clear, the length of time depending upon the thickness of the scales. They are then washed in water by sedimentation; that is, the test tube is filled with water and held in a vertical position until the scales have settled to the bottom. The water is then nearly all drawn off with a pipette, and the process is repeated. After all of the caustic potash has been removed, they are washed in 95 per cent alcohol and cleared in xylol. They should then be removed to a glass slide by means of a camel's-hair brush, and mounted in balsam. Since the last segment of the abdomen, the pygidium, is the only part of the insect used in classification, this is all that it is necessary to mount.

Neuroptera, Mecoptera, and Tricoptera. These forms are all pinned through the metathorax; the wings may or may not be spread, but it is usually best to spread the wings at least on one side of the body, the hind borders of the front pair of wings being brought forward at right angles to the body.

Lepidoptera (Fig. 480). In mounting Lepidoptera the pin is run through the mesothorax or metathorax; the wings are always spread, the front pair being brought forward until the hind margins are at right angles to the body. This rule is invariably followed both with the moths and butterflies. The smaller forms are usually

mounted on elbow pins, or on bits of fine silver wire (*minutien-nadeln*), which are stuck through bits of cork or pith and pinned like a cardboard point.

Diptera. In the Diptera the pin is run through the central part of the thorax, and the wings, if not spread, should be extended. In the long-legged flies, as the crane-fly, the legs should be supported until the specimen is dry. In fact, it is not a bad idea to place a permanent piece of cardboard on the pins holding such specimens. The smaller Diptera are usually mounted on wire or cardboard points.

FIG. 483. Showing method of pinning Coleoptera

(After Washburn)

Coleoptera (Fig. 483). All of the larger Coleoptera are pinned through the anterior inner portion of the right wing-cover. The wings are never spread, and but little attention need be given the specimens after pinning, as the legs usually adjust themselves. The smaller forms are mounted on cardboard points and should be glued on the side to reveal the undersurface.

FIG. 484. Showing method of pinning Hymenoptera

(After Washburn)

Hymenoptera (Fig. 484). These are pinned through the metathorax; the wings may or may not be spread. Some of the more slender forms, as the Ichneumon-flies, require a support until they are dry. Many of the parasitic Hymenoptera are mounted on slides in Canada balsam, but the usual way is to mount on points, either cardboard or wire.

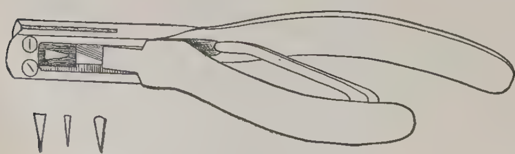

FIG. 485. Point punch

Mounting insects on points. General directions have already been given for mounting insects on points. It may be well, however, to mention some of the different types of points used in mounting insects. Micro-pins (Fig. 486, *d*) are largely used for mounting Lepidoptera, Neuroptera, and Diptera. These micro-pins (*minutien-nadeln*)

consist of very fine pieces of steel wire, and may be run through narrow strips of cork, pieces of paper, or small squares of cork, as shown in Fig. 486, *b*, *d*, and *e*. Elbow pins (Fig. 486, *c*) present a neater appearance than the micro-pins, and may be obtained of entomological supply companies.

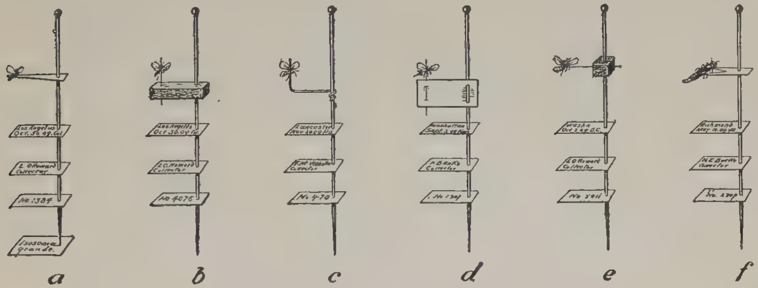

FIG. 486. Method of mounting insects on points

a, with a cardboard point; *b*, micro-pin in cork; *c*, elbow pin; *d*, micro-pin in paper; *e*, micro-pin in side; *f*, double point. (After Banks)

Most small Hemiptera and Coleoptera (Fig. 487) are mounted on small, triangular points cut from light Bristol board. Punches (Fig. 485) may be secured to cut these points accurately.

In mounting, the point is first placed on the pin at the required height. The end of the point is next dipped in gum shellac dissolved in alcohol and then touched to the ventral side of the insect. The insect will adhere to the point, and should be arranged in position with fine needles and forceps. The insect is mounted so that when the point is directed to the left, the head of the insect is away from the person. For insects having long bodies a double point should be used, as shown in Fig. 486, *f*.

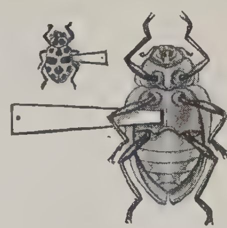

FIG. 487. Method of gluing beetle on paper point

(After Banks)

Whether micro-pins or points are used, care should be taken not to obscure more of the insect than is absolutely necessary.

Labeling. All specimens should be labeled as soon as possible after pinning. The label should consist of the name of the town and state, on the first line, and the date of collecting, on the

second line; some entomologists have the name of the collector on the third line. These labels should be printed in diamond type on the best paper procurable, and may be had for from twenty-five to thirty cents a thousand. In having labels printed, the space for the date should be left blank, to be filled in later. Only the best India ink and very fine crow-quill pens should be used. Below the locality label should be the accession number, the collection being numbered serially and each insect given a separate number, unless two or more of the same species were collected under the same conditions. The accession number should refer to the collector's notes, in which everything known about the insect is recorded. The date and place of collecting should again be recorded and the food plant or nature of the locality where the insect was found, etc.

Arrangement of insects. For the permanent storage of insect collections two general types of box are used. One consists of large glass-top drawers, about fifteen by eighteen inches, which fit into cabinets. The other type consists of separate boxes, with cork bottoms. For the beginner the latter type is probably the better. Numerous boxes are on the market, made from both cardboard and wood, the latter, of course, being far superior to the cardboard.

In selecting insect boxes care must be taken to obtain those having tight-fitting lids. This is absolutely essential in order to keep out certain Dermestid beetles, which, if they gain access to the collection, will quickly destroy it. Further precaution against these insects should be taken by placing flake naphthalene in the boxes. By far the best on the market is the Schmitt box (Fig. 488). This comes in two sizes, twelve by fifteen inches and eight and one half by fifteen inches, and is lined with pressed cork. In using the drawers, the insect pins are stuck into small blocks of wood, or into a lining of sheet cork, by means of pinning forceps (Fig. 478). The blocks[1] are cut to a uniform length and are made in multiple width. The width of the blocks used depends on the size of the insects and the number of specimens of each species. The advantage of this system is that it allows an indefinite amount of expansion of a collection, without necessitating the transfer of each individual insect.

[1] See Comstock's "Insect Life."

Whether the boxes or drawers are used, all of the specimens of one species should be kept together, which plan should be followed out in genera, families, and orders.

FIG. 488. A Schmitt insect box, opened to show arrangement of insects (After Banks)

Mounting insects on slides. Directions have already been given for the mounting of aphides and scale insects. The directions given for mounting scale insects may be used for mounting legs

or other hard parts of insects, where nothing but the chitinous portion is desired. For most purposes, however, such as mounting the legs of bees for laboratory use, or mounting small, hard-bodied insects, the following method will be found more desirable.

The insect or part of the insect to be mounted should first be placed in 85 per cent alcohol. This rule applies to mounting both fresh specimens and material previously preserved in alcohol or glycerin. After the insect has become thoroughly saturated, it should be transferred to 95 per cent alcohol and left for an hour or longer. The specimens should then be transferred to xylol and left until the alcohol is entirely replaced. The insect should then be placed in the center of the slide, the excess of xylol removed with a piece of blotting paper, and a drop of Canada balsam placed over the insect. The balsam should then be warmed slightly over an alcohol lamp, and a cover glass placed over it. Care must be taken not to get on more balsam than is necessary to cover the insect and fill out the space under the cover glass. For the beginner there is less liability of having air bubbles in the mount if the balsam is first placed on the slide and the insect laid on afterwards. However, it is much more difficult to arrange the wings and legs of the insect if mounted in this way.

Preserving material in liquids. Directions have already been given for collecting small, soft-bodied insects in liquid. When this material is first brought into the laboratory, it should be thoroughly washed in 50 per cent alcohol and then transferred to 85 per cent alcohol. If the specimens are large, soft-bodied larvæ, or insects of considerable size, the alcohol should be changed at least once before permanently storing the specimens. For permanently storing alcoholic material small, straight-necked vials will be found the most convenient. These should be of one-, two-, and four-dram sizes and fitted with the best cork stoppers procurable. The bottles should be numbered and labeled as in pinned insects, the labels being written on strips of good linen paper in India ink, which must be absolutely waterproof. These should be placed inside the bottles with the specimens. Numerous trays have been devised for holding alcoholic material, the one shown in Fig. 489 being very satisfactory. An improvement of this tray consists in

having either end extend up above the top of the bottles. This allows the trays to be stacked one above another without injuring the bottles.

Numerous substitutes for alcohol have been employed, of which a 4 per cent solution of formaldehyde is probably the best, as it is cheaper, tends to preserve the color, and does not harden the

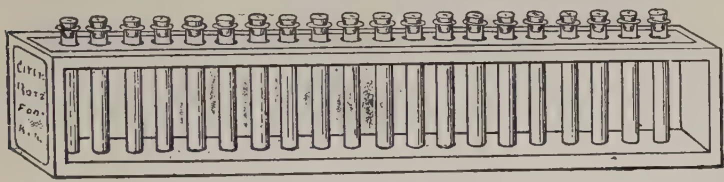

FIG. 489. The Marx tray for specimens in liquid

specimens. This, however, is not much superior to alcohol, and in many cases shrinks the specimens more than alcohol would.

Material intended for dissection may be treated as above, but if alcohol is used, should be permanently preserved in 70 to 85 per cent alcohol, to which 10 per cent of glycerin has been added.

Inflating insect larvæ. The larvæ of most of the Diptera, Coleoptera, and Hymenoptera are preserved in alcohol, as noted above. It has been found, however, that lepidopterous larvæ may be preserved much better by inflating them, the method of which is as follows:

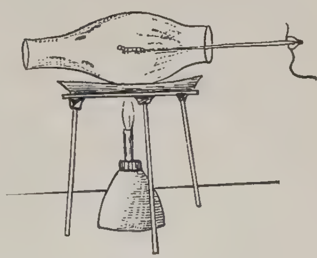

FIG. 490. Homemade apparatus for inflating larvæ (After Washburn)

The larvæ are brought to the laboratory alive, and when ready to be inflated are killed or stupefied in a cyanide bottle. This method will be found much better than killing the larvæ in the field, as they should be blown as soon as possible after they are killed. Remove the larva from the cyanide bottle and place it on a piece of blotting paper. A glass tube or pencil is next rolled over the body from the head toward the tip of the abdomen. This causes the alimentary tract to protrude, which is then snipped off at the anus by a pair of sharp-pointed scissors.

The rolling is then continued until the entire contents of the body have been forced out through the posterior end. A straw or a glass tube which has been drawn out to a fine point is next inserted through the opening. This may in turn be attached to a rubber tube and bulb, or the larva may be inflated by blowing gently through the tube. In order to keep the specimen on the end of the tube, it should be allowed to dry for a few minutes. To thoroughly dry the skin it is kept distended inside a glass lamp chimney, which rests in a pan of sand over a gas or alcohol flame, as shown in Fig. 490. When the skin is thoroughly dried, it is removed from the glass tube and may then be mounted on an elbow pin by bending the point of the elbow into a loop, which is dipped into glue and inserted into the opening in the abdomen. Another method is shown in Fig. 491.

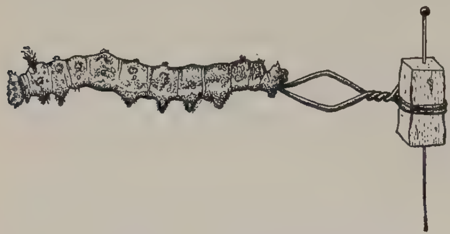

FIG. 491. Method of mounting inflated larvæ (After Washburn)

Dissecting instruments. The number of different instruments required for the study of the anatomy of insects is not great. However, owing to the small size of the specimens studied, the instruments should be of the very best material.

Forceps. Forceps should be of two kinds, curved-pointed and straight-pointed (Fig. 492). Both pairs should have very fine points which are slightly roughened.

Scissors. Curved scissors will be found very useful in carrying on minute dissecting work, the difficulty being to secure a pair that will cut entirely to the point. In using the fine-pointed scissors, care must be exercised not to strain them by cutting too thick objects.

Scalpels. These are of less importance in entomological work than in most other forms

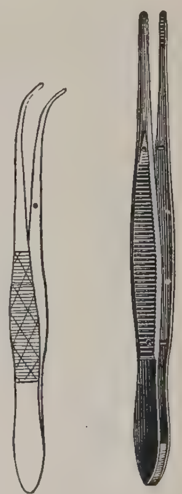

FIG. 492. Forceps, curved-pointed and straight-pointed

of dissecting, but two or three scalpels of various shapes will be found useful. The short, curved, sickle-shaped scalpel will be used in general dissection more than any other.

Needles. These are really of more importance than the scalpel. They may be made by forcing the eye of an ordinary needle into a small stick about the size of a lead pencil. Much more satisfactory needle handles may be secured of the supply companies, with arrangements for removing and exchanging the needle. One should be provided with three of four of these needle holders and a number of needles bent into various shapes, — hooks of different sizes, and curved and straight needles.

Brushes. An assortment of camel's-hair brushes will be found useful on the dissecting table.

Pins. For holding the dissected specimens in position ordinary insect pins will be found most convenient. The larger sizes, Nos. 4, 6, and 8, are well adapted for minute dissection. A few large pins with black glass heads will also be found useful for heavier work.

Microscopes and lenses. Every collector should be provided with at least one good pocket lens. For most work a half-inch lens, procurable of any microscope supply company, will be found sufficient. For very small insects, however, a one-fourth-inch lens will be found much better.

Dissecting microscopes are almost an essential if careful work in insect anatomy is to be done. Various types of these are sold by all optical companies. Compound microscopes are essential for very minute work, but for studying the general anatomy of insects they can be more easily dispensed with than the dissecting microscope.

Dissecting trays. Dissecting trays, as found on the market, consist of shallow tin or porcelain trays ranging in size from four by five to twelve by fifteen inches, with a depth of from one to three inches. The bottoms of these trays are usually covered with paraffin or beeswax, so that the specimens may be pinned out under water. Homemade trays may be constructed by obtaining tin pans of the proper size, and having two or three short pieces of wire soldered to the bottom. The ends of the wire should be left projecting, so that when hot paraffin or beeswax is poured into the pan, the wire will hold it firmly in place and prevent it from floating when in use.

This sort of dissecting tray works very well for rough dissection, where nothing more than a hand lens is required. It has the objection, however, of the projecting sides, which frequently prevent one from manipulating the dissecting instruments as desired.

By far the most successful dissecting tray for insect work that we have used is made as follows: A glass plate four by five inches is thoroughly washed in alcohol in order to remove all traces of dirt. This is then placed in a shallow pan which has been previously coated with vaseline or oil. A mixture of four parts paraffin and one part beeswax is next poured over the glass plate to a depth of about one inch. After this is thoroughly cool, it is removed from the pan and the paraffin trimmed off to the edge of the glass plate. A trough is scraped out in the center of the plate to accommodate the body of the insect to be dissected. After a little experience one can very quickly regulate the size and shape of this trough to the best advantage. A sufficient amount of paraffin should be left beneath the insect to permit of its being firmly pinned in position. The work will also be greatly facilitated if glycerin, to which an excess of chloral hydrate has been added, is used as a dissecting medium in place of water. This form of tray has a number of distinct advantages. In the first place, the work can be carried on entirely with the dissecting microscope, or even a low power of the compound microscope. There are no projecting sides to interfere with the manipulation of the instruments, and if the dissection is not

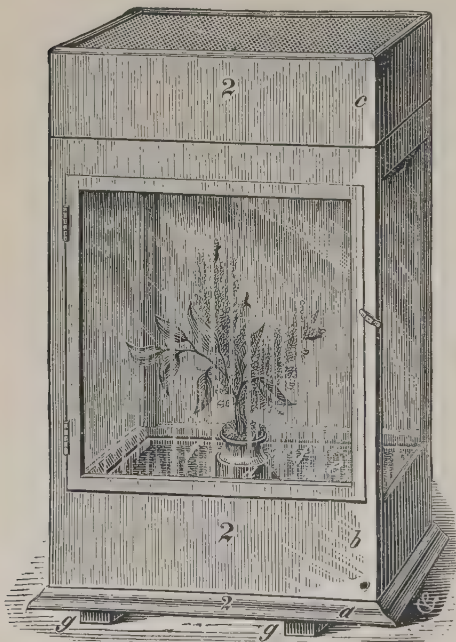

FIG. 493. The Riley breeding cage

completed, it may be temporarily sealed by covering with a glass plate which is firmly pressed in position. The glycerin has many distinct advantages over water, its density holding the more delicate structures in position, and at the same time it has a higher index of refraction. Plates of various sizes and depths may be easily constructed to meet different requirements.

FIG. 494. A lamp-chimney breeding cage

(After Banks)

Rearing insects. If one wishes to study the life history of insects, or if desirous of procuring especially fine specimens, by far the best method is to rear them under artificial conditions. In this work an attempt must always be made to simulate natural conditions as closely as possible. There is less liability of the larvæ being parasitized if they are placed in a breeding cage when quite small. Numerous breeding cages have been constructed for the purpose of rearing larvæ. Of these, one of the best is shown in Fig. 493. This consists of a frame with a glass door on one side, the other three sides being covered with cheesecloth. If possible, the food plant is placed in a flowerpot inside the breeding cage. If this is impracticable, twigs and branches can be placed in the cage in bottles of water, the top of the bottle being stuffed full of cotton to prevent the larvæ from drowning. Another simple breeding cage for smaller insects is made by placing a lantern globe or lamp chimney, the top of which is covered with a square of cheesecloth, over the food plant (Fig. 494) in a flowerpot. The food material should be changed frequently, so that it may be kept fresh and sufficient.

FIG. 495. A simple aquarium for aquatic larvæ

(After Washburn)

For rearing large quantities of larvæ an open tray three by five feet is most convenient.

The sides of the tray are made of light six-inch boards, and the bottom is formed by a piece of cheesecloth. Four-inch strips are next tacked to the top of the tray, so that they project inward around it. The inside of the projecting ledge formed by the four-inch strips is coated with tanglefoot. The food and the larvæ are placed in the tray on the cheesecloth. The larvæ are easily observed all the time, and the food material may be quickly changed, while the tanglefoot prevents the escape of the larvæ. The larvæ, however, are not protected from parasites, and the pupæ must be removed and placed in tight cages before the adults emerge.

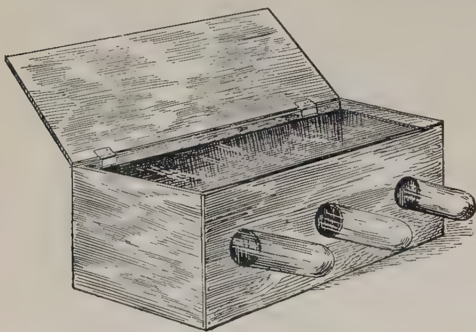

Fig. 496. Breeding cage for parasites (After Banks)

Aquatic larvæ and nymphs may be reared in any suitable aquarium (Fig. 495), but only larvæ of the same size should be kept together, and care should be taken to separate those which are predacious upon one another.

Numerous cages for the study of special insects have been devised, as the Comstock root-cage, devices for studying the life history of ants, the limb cage for rearing insects out of doors in their natural habitat, and the breeding cage for parasites (Fig. 496).

For further methods, consult the following books:

L. O. Howard, The Insect Book. (Doubleday, Page & Co.)
W. J. Holland, The Moth Book. (Doubleday, Page & Co.)
V. L. Kellogg, American Insects. (Henry Holt and Company)
J. H. and A. B. Comstock, Insect Life. (D. Appleton & Co.)

APPENDIX

I. DEALERS IN ENTOMOLOGICAL SUPPLIES

Ward Natural Science Establishment, Rochester, N.Y.
The Kny-Scheerer Co., 404 West Twenty-seventh St., New York City
M. Abbott Frazer, 93 Sudbury St., Boston, Mass.
A. Smith and Sons, 269 Pearl St., New York City
Charles C. Reidy, 432 Montgomery St., San Francisco, Cal.
The Simplex Net Co., Ithaca, N.Y. (Nets.)
Bausch and Lomb, Rochester, N.Y. (Microscopes, lenses, instruments, etc.)
Queen & Co., 1010 Chestnut St., Philadelphia, Pa. (Microscopes, lenses, instruments, etc.)
The Spencer Lens Co., Buffalo, N.Y. (Microscopes, lenses, instruments, etc.)
The Wiegner Printery, 2234 North Twenty-ninth St., Philadelphia, Pa. (Labels.)
C. V. Blackburn, 32 Chestnut St., Stoneham, Mass. (Labels.)

II. ADDRESSES OF STATE AGRICULTURAL EXPERIMENT STATIONS AND OF STATE ENTOMOLOGISTS

Alabama, Auburn
Arizona, Phœnix
Arkansas, Fayetteville
California, Berkeley
Colorado, Fort Collins
Connecticut, New Haven
Delaware, Newark
Florida, Gainesville
Georgia, State Entomologist, Atlanta
Hawaii, Honolulu
Idaho, Moscow
Illinois, State Entomologist, Urbana
Indiana, Lafayette
State Entomologist, Indianapolis
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Kentucky, Lexington
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Maine, Orono
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Michigan, East Lansing
Minnesota, St. Anthony Park
Mississippi, Agricultural College
Missouri, Columbia
Montana, Bozeman
Nebraska, Lincoln
Nevada, Reno

New Hampshire, Durham
New Jersey, New Brunswick
New Mexico
New York, Geneva
Cornell University Agricultural Experiment Station, Ithaca
State Entomologist, Albany, N.Y.
North Carolina, West Raleigh
State Entomologist, Raleigh
North Dakota, Agricultural College
Ohio, Wooster
Oklahoma, Stillwater
Oregon, Corvallis
Pennsylvania, State Zoölogist, Harrisburg
South Carolina, Clemson College
South Dakota, Brookings
Tennessee, Knoxville
Texas, College Station
Utah, Logan
Virginia, Blacksburg
Washington, Pullman
West Virginia, Morgantown
Wisconsin, Madison
United States Department of Agriculture, Bureau of Entomology, Washington, D.C.

III. A LIST OF BOOKS FOR THE REFERENCE LIBRARY

General Entomology

Comstock, J. H. A Manual for the Study of Insects. (Comstock Publishing Co., Ithaca, N.Y., 1895.)

Comstock, J. H. and A. B. Insect Life. (D. Appleton & Co., New York City, 1901.)

Folsom, J. W. Entomology, with Special Reference to its Biological and Economic Aspects. (J. B. Lippincott and Co., Philadelphia, Pa., 1906.)

Howard, L. O. The Insect Book. (Doubleday, Page & Co., New York, 1904.)

Kellogg, V. L. American Insects. (Henry Holt and Co., New York, 1905–1908.)

Packard, A. S. A Text-Book on Entomology. (The Macmillan Company, New York, 1898.)

Sharp, D. The Cambridge Natural History. Insects. 2 vols. (The Macmillan Company, London, 1895–1899.)

(The works of Folsom, Kellogg, and Packard above are especially strong concerning the anatomy of insects.)

Butterflies and Moths (*Lepidoptera*)

Comstock, J. H. How to Know the Butterflies. (D. Appleton & Co., New York, 1904.)

French, G. H. The Butterflies of the Eastern United States. (J. B. Lippincott and Co., Philadelphia, 1886.)

HOLLAND, W. J. The Butterfly Book. (Doubleday, Page & Co., New York, 1905.)

The Moth Book. (Doubleday, Page & Co., New York, 1903.)

ELIOT, IDA M., and SOULE, CARO G., Caterpillars and their Moths. (The Century Co., 1902.)

DICKERSON, MARY C., Moths and Butterflies. (Ginn and Company, Boston, 1905.)

ECONOMIC ENTOMOLOGY

SMITH, J. B. Economic Entomology. (J. B. Lippincott and Co., Philadelphia, 1896.)

SANDERSON, E. D. Insects Injurious to Staple Crops. (John Wiley and Sons, New York, 1902.)

Insect Pests of Farm, Garden and Orchard. (John Wiley and Sons, New York, 1912.)

CHITTENDEN, F. H. Insects Injurious to Vegetables. (Orange Judd Co., New York, 1907.)

SAUNDERS, WM. Insects Injurious to Fruits. (J. B. Lippincott and Co., Philadelphia, Pa., 1883.)

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ANNOUNCEMENTS

PRATT'S ZOÖLOGIES

A Course in Invertebrate Zoölogy

(Revised Edition)

By Henry S. Pratt, Haverford College

8vo, cloth, xii + 228 pages, $1.25

This manual for colleges, normal schools, and academies contains specific directions for the dissection of forty invertebrate animals, arranged so as best to utilize the time of both student and instructor.

The object of the course is to teach comparative anatomy. Each of the larger groups of invertebrates is studied as a whole, instead of in the usual detached types of the different groups. By this method the attention is constantly directed to the structural features which characterize the entire group under consideration.

A classification of animals based upon relationships is given in an appendix, together with short definitions of the groups mentioned. The position in the system of each form studied and its relationships with other animals may thus be kept in mind.

A Course in Vertebrate Zoölogy

By Henry S. Pratt, Haverford College

8vo, cloth, x + 299 pages, $1.50

A companion volume to the author's "Invertebrate Zoölogy," and, like that book, intended for use in colleges, in normal schools, and in high schools.

It gives detailed directions for the dissection of seven animals representing the five classes of the Vertebrata; namely, the dogfish, the perch, Necturus, the frog, the turtle, the pigeon, and the cat.

GINN AND COMPANY Publishers